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MULTI-PART SEISMIC CABLE

1. FIELD OF THE INVENTION

This invention relates generally to seismic cable systems, and, more particularly, to a robust and reliable seismic cable system.

2. DESCRIPTION OF THE RELATED ART

Subsurface hydrocarbon accumulations are increasingly found in geologically complex areas. The ability to conduct accurate seismic surveys may help improve the discovery rates and even the production of such accumulations. Seismic surveying is a method of stimulating a geological subsurface formation with, *e.g.*, electrical, magnetic, and/or acoustic signals to acquire seismic data about the formation. From this data, one can predict tell whether the formation contains hydrocarbon deposits and, if so, where.

One type of seismic survey is generally referred to as a "marine" survey because it is typically conducted at sea, although this is not necessarily always the case. During marine seismic surveys, seabed seismic cable systems are deployed to the bed of a sea, lake, river, or marsh. The water depth may range from several thousand meters up to the water/land transition zone. Water currents of considerable speed may pass over the cable system and create instability and deterioration of the seismic data quality.

Seabed seismic cable systems generally are designed to meet two conflicting goals. First, the cable system must be robust and resistant to damage. For example, the cable

system must survive and operate at great water depth. Also, the cable system may be roughly handled during deployment and retrieval. Second, the cable system should be sensitive to acoustic vibrations and not compromise the quality of data recorded by the sensor units.

Although there are several types of seabed seismic cables, there are generalities in construction. A seabed seismic cable includes three main elements: stress members, leads, and a sheath. One or several stress members take the tension that can be applied to the seabed seismic cable during deployment and retrieval operations to protect other elements of the cable. The leads, which may be electrical or optical, transmit power and/or data, in analog or digital format, along the cable for collection and processing, *e.g.*, on a survey vessel. The sheath is a skin, jacket or extrusion matrix protecting the seabed seismic cable against, notably, water ingress.

One type of seabed cable is known as an "ocean bottom cable" ("OBC"), and is typically equipped with "takeouts." A full length of conventional OBC is seismic built, the jacket is then opened at the location were the sensors are located, and leads are extracted from the cable to form a take-out and connected to the sensors. The sensors are then attached to the cable.

These types of cable are prone to water intrusion, electrical leakage, and wire kinking, as the take-outs are submitted to a high level of strain during cable handling. These cables usually have an asymmetric cross-section at the sensors, and the response will change depending on how the sensors rest on the seafloor. These types of cables also expose the seismic receivers and the takeouts to a number potentially damaging obstacles on the seabed, thereby reducing the reliability of the collected data. Furthermore, because the takeouts are

extracted from the cable and not a separate component, the entire cable may need to be replaced if the takeouts are damaged, which can be expensive and time-consuming.

Improvements to this type of apparatus appear in U.S. Patent No. 6,294,727 to Orlean, which provides for an "overmolding" of the cable and the sensor units. Improvements also appear in U.S. Patent and 6,333,898 to Knudsen *et al.* and U.S. Patent No. 6,041,282 to Wardeberg *et al.* (collective referred as "steel armored cables"), which provide for a preparation of steel armored cable without takeouts. However, the Orlean and steel armored cables still suffer from the drawbacks mentioned above, including water intrusion, electrical leakage, and wire-kinking. Furthermore, the Orlean and steel armored cables usually suffer from the asymmetric cross-section at the sensor units.

Another type of seabed seismic cable system is commonly referred to as a logging type cable. Logging type cables typically have a full electrical/optical termination at each sensor unit, resulting in a high number of connection points. The high number of connection points negatively impacts the cable's reliability. Furthermore, the increased number of terminations makes the sensor unit large and heavy, which negatively impacts data quality.

Yet another type of seabed seismic cable system comprises conventional cables with sensor units integrated inside a protective cable jacket. One variation is known as a "streamer type" cable. The streamer type cable is an evolution of a towed seismic streamer for deployment on the seabed. The streamer type cable comprises spacers, sensor units, and a filler, which usually is oil. The streamer type cable has a constant diameter and therefore occupies a large volume when stored. An alternative variation is known as a "solid cable." One example of the solid cable is shown in U.S. Patent No. 6,333,897 to Knudsen *et al.*,

which can be produced with a constant diameter or a variable diameter. Both the constant diameter and the variable diameter cables pose potentially serious drawbacks. The cable with a constant diameter is extremely large, heavy and stiff. The cable with a variable diameter is difficult to manufacture.

The present invention is directed to overcoming, or at least reducing the effects of, one or more of the problems set forth above.

SUMMARY OF THE INVENTION

The invention comprises a seismic cable and a method for assembling such a seismic cable. The apparatus comprises seismic cable including a support cable and a signal cable attached to the support cable at a plurality of points spaced along the length of the signal cable. The seismic cable also includes at least one sensor module disposed on the signal cable. The method includes attaching a support cable to a signal cable at a plurality of points spaced along the length thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify like elements, and in which:

FIG. 1 illustrates a seismic survey vessel from which a seismic cable constructed and operated in accordance with the present invention is deployed;

FIG. 2A to **FIG. 2C** illustrate a first embodiment of the seismic cable of **FIG. 1** in accordance with the present invention wherein:

- **FIG. 2A** illustrates in a partially sectioned view of the seismic cable of **FIG. 1**, in accordance with one embodiment of the present invention;
- **FIG. 2B** illustrates the support cable of **FIG. 2A** cross-sectioned along line 2B-2B in **FIG. 2A**; and
- **FIG. 2C** illustrates the signal cable of **FIG. 2A** cross-sectioned along line 2C-2C in **FIG. 2A**;

FIG. 3 illustrates a partial view of the seismic cable of **FIG. 1**, in accordance with one particular embodiment of the present invention in which the support and signal cables are attached by the electronics modules;

FIG. 4 illustrates a storage and deployment mechanism for the seismic cable of **FIG. 1**, in accordance with a second embodiment alternative to that in **FIG. 3** in which the support and signal cables are joined by a zipper mechanism;

FIG. 5 illustrates a partial, perspective, cross-sectioned view of the seismic cable of **FIG. 1**, in accordance with a third embodiment alternative to those in **FIG. 3** and in **FIG. 4** in which the support and signal cables are fabricated together and then separated by a rip-cord;

FIG. 6 illustrates a partial plan view of the seismic cable of **FIG. 1**, in accordance with a fourth embodiment in which the support cable and the signal cable are attached by a rigid arm; and

FIG. 7A and **FIG. 7B** illustrate a fifth embodiment in a side, plan view and in an end, partially sectioned view (along line 7B-7B), respectively, which the support and signal cables are attached by the housings of the sensor modules.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

FIG. 1 illustrates a seismic survey system 100 in which a seismic survey vessel 105 has deployed a seismic cable 110 to the bed 115 from the surface 120 of a body of water 125. In the illustrated embodiment, the body of water 125 is part of an ocean. Consequently, the

bed 115 is a seabed (or, ocean floor). However, the invention is not so limited, as the invention may used for surveys conducted in fresh and brackish waters.

FIG. 2A illustrates a seismic cable 110 in accordance with one embodiment of the present invention. The seismic cable 110 comprises a support cable 205 and a signal cable 210 attached to the support cable 205 at a plurality of points 215 spaced along the length thereof. In the illustrated embodiment, the signal cable 210 further comprises a plurality of sensor modules 220, which will be discussed further below. In one embodiment, the spacing of the points 215 is approximately proportional to a length of the sensor modules 220 so that the points 215 are located between each of the sensor modules 220. However, the present invention is not so limited. In alternative embodiments, the points 215 may be located at any desirable location. For example, the points 215 may be located between every other sensor module 220 or between successive pluralities of sensor modules 220. For another example, a plurality of points 215 may be located between each pair of sensor modules 220.

As is shown in **FIG. 2B**, the support cable 205 includes one or more stress members 225 (only one indicated) providing tension to the seismic cable 110. The stress members 225 may be any type of stress member known to the art for handling tension in seismic cables. Examples of suitable stress members 225 include, but are not limited to, steel wire and utility cable. If more than one stress member 225 is employed, as in the illustrated embodiment, the stress members 225 may be cabled together in any suitable fashion known to the art. For instance, in the illustrated embodiment, the stress members 225 are jacketed together, *i.e.*, cabled together by enclosure in a jacket 230. Furthermore, in some embodiments, the support cable 205 may be filled with a filler 235 to, *e.g.*, help protect against water intrusion. The filler 235 may be of any suitable type known to the art.

As is shown in **FIG. 2C**, the signal cable 210 comprises, *inter alia*, a plurality of signal leads 240, and, in the illustrated embodiment, one or more power leads 260. The signal leads 240 may include electrical leads 245 such as a twisted wire pair of leads, a coaxial cable, and the like. The signal lead 240 may also include one or more optical fibers 250. As with the support cable 205, these elements may be cabled together in any suitable fashion known to the art. For instance, in the illustrated embodiment, the leads 240, 245, 250, 260 are jacketed together, *i.e.*, cabled together by enclosure in a jacket 265. Furthermore, in some embodiments, the signal cable 210 may be filled with a filler 270 to, *e.g.*, help protect against water intrusion. The filler 270 may be of any suitable type known to the art. In the illustrated embodiment, the signal cable 210 also includes a stress member 275 for providing extra support on forces exerted against the signal cable 210, although the invention is not so limited. In alternative embodiments, the signal cable 210 may not include the stress member 275 or may include a plurality of stress members 275.

Returning to **FIG. 2A**, the signal cable 210, in the illustrated embodiment, further comprises one or more sensor modules 220. The sensor module 220 includes one or more sensors (not shown). Examples of sensors include, but are not limited to, geophones, accelerometers, hydrophones, tilt meters, and magnetometers.

These sensors generate data in the course of survey operations and transmit that data over the signal cable 210 in a conventional manner. The sensors may include electronics for conditioning the signal and/or digitizing it. The sensor module 220 is typically connected to the signal cable 210 by one or more the sensor leads 240, 245, 250, 260 shown in Figure 2C. Note that the composition of sensors in each sensor module 220 may be the same or may be unique, depending on the implementation. To some degree, the choice of sensors may

influence the number and implementation of the signal and power leads (*e.g.*, the leads 240, 245, 250, 260 in **FIG. 2C**).

The data from the sensors may be transmitted to one or more electronics modules (not shown in **FIG. 2A**) located along the seismic cable 110 or between cable sections. The electronics module is connected to the signal cable the signal cable 210 by one or more of the signal leads (*e.g.*, the signal leads 240, 245, 250, 260 in **FIG. 2C**) of the signal cable. Alternatively, the functionality of the electronics module may reside in one or more of the sensor modules 220 in some alternative embodiments. The electronics module serves as a data transmission and power hub for the sensor modules 220. In one embodiment, the electronics module may comprise a high bandwidth bus capable of transmitting data between other electronics modules and to a computer or other computing device (not shown) on the seismic survey vessel 105 or at a remote location. In an alternative embodiment, the sensor module 220 may be connected to the signal cable 210 by a data bus (not shown). Regardless, one important function of the electronics module is to collect and forward the data generated and transmitted by the sensor modules.

In one embodiment, the sensor module 220 is sufficiently sealed to protect against water intrusion and physical damage. However, in alternative embodiments, the seismic cable 110 may be enclosed by a sheath, or protective outer covering (not shown).. In embodiments wherein the support cable 205 includes leads, the support cable 205 may also be enclosed by a sheath (not shown). The sheath protects sensitive electronics such as the signal cable 210 and sensor module 220 from water intrusion and physical damage. The protective outer covering can be any skin, jacket, or extrusion matrix known in conventional practice.

Although the support cable 205 bypasses the sensor module 220 as illustrated in **FIG. 2A**, in an alternative embodiment, a groove can be provided in the sensor module 220 such that the support cable 205 passes through the sensor module 220 via the groove. The support cable 205 can be acoustically decoupled from the sensor module 220 by one or more acoustic decoupling devices (not shown) between the groove and the support cable 205, such as springs or elastic devices, as will be discussed further below.

As was mentioned above, the signal cable 210 is attached to the support cable 205 at a plurality of points 215, shown generically in **FIG. 2A**. The invention admits wide variation in how this attachment may be accomplished, and may employ virtually any suitable attachment mechanism. **FIG. 3** – **FIG. 6** each illustrate various alternative embodiment employing and implementing different attachment mechanisms. More particularly:

- **FIG. 3** illustrates an embodiment in which the attachment is made through electronics modules 305 being connected to both a signal cable 210 and a support cable 205-A;
- **FIG. 4** illustrates the deployment of an embodiment in which the attachment is made through a zipper mechanism;
- **FIG. 5** illustrates an embodiment in which the support cable 205 and the signal cable 210 are separated after fabrication by a rip-cord 505; and
- **FIG. 6** illustrates an embodiment in which the attachment is made by a rigid arm 610.

Each of these alternative embodiments shall now be discussed more fully in turn.

FIG. 3 illustrates one embodiment of the seismic cable 110, in which an electronics module 305 separating two support cable sections referred in **FIG. 3** as a left support cable

section 205-A and a right support cable section 205-B section. As mentioned, the electronics module 305 is placed at intervals along the seismic cable 110 of **FIG. 1** and **FIG. 2A** and is generally placed between the support cable sections 205-A, 205-B.

As illustrated in **FIG. 3**, the signal cable 210 is directly connected to the electronics module 305. In one embodiment, the left support cable section 205-A terminates on one side of the electronics module 305 and begins anew at the right support cable 205-B at another side of the electronics module 305. In an alternative embodiment, the support cable sections 205-A, 205-B pass through the electronic module 305.

Although not illustrated in **FIG. 3**, it should be appreciated that at least of a portion the support cable sections 205-A, 205-B and signal cable 210 may be connected by some other attachment mechanism in addition to the attachment provided at the sensor module 305. For instance, the embodiment of **FIG. 3** might also employ the rigid or semi-rigid arm 610 in **FIG. 6**, discussed more fully below. Thus, some embodiments might use several different types of attachment mechanisms.

FIG. 4 illustrates an embodiment of the seismic cable 110 in **FIG. 1** alternative to that of **FIG. 3**. A storage and deployment mechanism 405 is shown, which stores a continuous length of support cable 205 in a support cable storage 410 and a continuous length of signal cable 210 in a signal cable storage 415. As mentioned, the sensor module 220 and the electronics module 305 are directly connected to the signal cable 210 and are stored along with the signal cable 210 in the signal cable storage 415. It should be appreciated that although the support cable storage 410 and the signal cable storage 415 are illustrated in a

common "spool" configuration, any method of storing a continuous length of cable known in conventional practice may be used.

The support cable 205 and the signal cable 210 are attached at one end by a zipper mechanism 420. As the support cable 205 is deployed from the support cable storage 410 and signal cable 210 is removed from signal cable storage 415, the zipper mechanism 420 is guided in the direction of the spools 410, 415, thereby automatically attaching the support cable 205 with the signal cable 210. The zipper mechanism 420 can be any mechanism known in the art for automatically clamping two members in a zipping fashion. For example, the zipper mechanism 420 may comprise a plurality of clamps that are individually operated to attach the support cable 205 with the signal cable 210. The plurality of clamps may be located on the support cable 205, the signal cable 210, or both. Another example of the zipper mechanism is a Velcro-based solution. Yet another example of a zipper mechanism is strong thread that attaches the signal cable to the support cable by sowing, wrapping or knitting.

Because the sensor module 220 and the electronics module 305 are attached to the signal cable 210 without tension, the signal cable 210 will be subjected to relatively gentler handling. Furthermore, this embodiment of the seismic cable 110 allows for greater operation depth and easier handling in adverse weather. The design also allows easier and faster replacement of component parts in the seismic cable 110. Still further, because the signal cable 210 and support cable 205 can be stored without tension, less space is needed in the signal cable storage 415 and the support cable storage 410, respectively. One important feature of this arrangement is that the signal cable 210 is handled and stored with virtually no tension. This creates an opportunity for the cable designer to avoid certain conflicting requirements like cable strength vs. unwanted inter-cable acoustic coupling.

Note that, in some embodiments, the electronics module can be carried as part of the support cable 205, as opposed to the signal cable 210. In such an embodiment, the support cable 205 comprises one or more electronics modules 305 (first shown in **FIG. 3**) connected to one or more leads in the support cable 205. The leads may be electrical or optical, depending on their purpose and the particular embodiment. The leads may be for transmitting data and power for the operation of the electronics modules 305. For instance, signal leads (*e.g.* the signal leads 240 shown in Figure 2C) may be used to transmit data from the electronics modules 305 to, *e.g.*, a computing device (not shown) located on the seismic survey vessel 105 (first shown in **FIG. 1**) or at the remote location. Similarly, leads may be employed for transmitting power from the survey vessel 105 to the electronics modules 305.

One example of such a seismic cable 110 is illustrated in **FIG. 5**. The support cable 205 and the signal cable 210 are manufactured together in one continuous unit and substantially enclosed by the protective outer covering 230. The signal cable 210 can be detached over short sections where the sensor modules (not shown in **FIG. 5**) are desired by pulling a rip-cord 505. Detaching the signal cable 210 from the seismic cable 110 leaves an empty groove 510. If the outer covering 230 is comprised of a thermoplastic, the rip-cord 505 can be heated by electrical current, for example, to ease pulling the rip-cord 510. Once the signal cable 210 is detached, it can be terminated and connected to the sensor module 220. The support cable 205, in the embodiment of **FIG. 6**, includes several signal leads 515 (only one indicated) over which control and data signals may be transmitted and a power lead 520 over which the electronic modules 320 may be powered.

FIG. 6 illustrates an alternative embodiment of the attachment mechanism 215 of **FIG. 2A**. Aarm 610 separates the support cable 205 from the signal cable 210 at a sufficient distance such that the support cable 205 and the signal cable 210 do not contact during deployment. In alternative embodiments, the arm 610 may be rigid or semi-rigid. A semi-rigid arm 610 will flex along the direction of the signal cable 210 but be rigid in the direction of rotation about the signal cable 210. The arm 610 is attached to the support cable 205 by a clamp 615. The arm 610 should generally be attached loosely to the signal cable 210 such that excess torsion is not introduced into the signal cable 210. For example, as illustrated in **FIG. 6**, the arm 610 is attached to the signal cable 210 by a bearing 620 that allows the signal cable 210 to rotate freely around the signal cable 210 and move axially between two stop clamps 625.

FIG. 7A and **FIG. 7B** illustrate another alternative embodiment in which the support cable 205 and the signal cable 210 are attached by the housings of the sensor modules 220 themselves. The view in **FIG. 7B** is from the direction of the arrow 705 in **FIG. 7A** and sectioned along the line 7B-7B in **FIG. 7A**. As was alluded to earlier, the support cable 205 is acoustically decoupled from the housing 710 of the sensor module 220 by a plurality of elastic devices 715 (only one indicated), such as springs, as is shown in **FIG. 7B**. In some alternative embodiments, the elastic devices 715 may be omitted. Note that a plurality of electrical connections 725 (only one indicated) are conceptually illustrated between the signal cable 210 and the sensor module 220.

The elastic devices 715 are positioned between the support cable 705 and the sensor housing 710 in the groove 720 defined by the sensor housing 710 and through which the support cable 205 runs. Such decoupling techniques are known to the art, and one is more

fully disclosed in International Patent WO0214905, published February 21, 2002, in the name of James Martin, Nicolas Goujon, Frederik Naes, and Rune Voldsbekk.., and entitled "A HOUSING FOR A SEISMIC SENSING ELEMENT AND A SEISMIC SENSOR." However, other techniques may also be employed in alternative embodiments. For instance, some embodiments, the support cable is decoupled from the sensor housing 710 by being permitted to slide freely through the groove 720 relative to the sensor module 220.

The present invention facilitates acoustic decoupling of the sensor modules 220—and, hence, the sensors—from the stress member 205, which is rigid and under tension, and therefore improves the data quality recorded by the system 100. The various embodiments described herein provide a robust cable 110 capable of being subjected to rough handling when the cable 110 is deployed and/or retrieved. The robust cable 110 is further capable of being subjected to great water depth and pressure. Although the cable 110 is substantially robust, the cable 110 delivers higher data quality than previous cables. More particularly, in its various aspects and embodiments, the invention provides the following advantages over the state of the art:

- higher reliability of the connections to the sensor modules 220, as takeouts are eliminated;
- reduced number of connections;
- increased cable strength as terminations of the stress member 205 are eliminated;
- improved sensor-to-ground coupling due to the smaller and lighter sensor module 220;
- more precise data recording independent of how the sensor module 220 rests on the seafloor due to axial symmetry of the cable 110 and sensor module 220;

- mechanical decoupling between the sensor module 220 and the support cable, thus freeing the sensor module 220 from the stresses on the stress member 205 and improving data quality;
- high data quality independent of water depth;
- higher possibility for the same axial symmetry for the cable 110 as for the sensor module 220 and for positioning the sensor module 220 closer to the center of gravity of the sensor module 220—thereby providing consistent and repeatable independent of how the sensor module 220 lies on the seafloor;
- higher modularity of cable construction providing increased reparability, reconfiguration possibilities, improved depth-appropriate assembly, and even the possibility of omitting stress carrying support for shallow water operations;
- easier handling procedures, as the stress member 205 and the signal cable 210 can be separated for storage and shipping; and
- safer handling for components since the sensor module 220 can be stored separately from the stress member 205, thereby reducing danger to the sensor module 220 from tension on the stress member 205.

Note that not all of these advantages will be realized in every embodiment of the invention. Still other advantages may become apparent to those skilled in the art having the benefit of this disclosure.

This concludes the detailed description. The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the

particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

CLAIMS

1. A seismic cable, comprising:

a support cable;

a signal cable attached to the support cable at a plurality of points spaced along the length of the signal cable; and

at least one sensor module disposed on the signal cable.

2. The seismic cable of claim 1, further comprising a first sheath enclosing the support cable and the signal cable.

3. The seismic cable of claim 2, wherein the first sheath comprises at least one of is a skin, a jacket or an extrusion matrix.

4. The seismic cable of claim 1, wherein the support cable includes a plurality of strengthening members.

5. The seismic cable of claim 4, wherein the strengthening members are cabled by a second sheath.

6. The seismic cable of claim 1, wherein the support cable includes at least one of a signal lead and a power lead.

7. The seismic cable of claim 6, further comprising an electronics module powered over the power lead and capable of transmitting data over the signal lead.

8. The seismic cable of claim 7, wherein the support cable is sectioned.

9. The seismic cable of claim 1, wherein the signal cable includes a plurality of leads cabled by a third sheath.

10. The seismic cable of claim 1, wherein the signal cable includes at least one strengthening member.

11. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to the signal cable.

12. The seismic cable of claim 1, wherein the sensor modules transmit data and receive power over the signal cable.

13. The seismic cable of claim 1, further comprising:

a plurality of sensor modules electrically connected to and distributed along the signal cable; and

a plurality of electronics modules by which the signal cable is attached to the support cable at the points.

14. The seismic cable of claim 1, wherein the electronics modules are electrically connected to the signal cable at the points and mechanically connected to the support cable.

15. The seismic cable of claim 1, wherein the signal cable is attached to the support cable by a zipper mechanism.

16 The seismic cable of claim 1, wherein the plurality of points are spaced along the length of the signal cable in proportion to a length of the sensor module.

17. The seismic cable of claim 16, wherein the plurality of points are positioned between adjacent sensor modules

18. The seismic cable of claim 16, wherein the separations are created by pulling a rip cord fabricated in the seismic cable to detach the signal cable from the support cable.

19. The seismic cable of claim 1, further comprising a plurality of arms mechanically affixed to the support cable and rotationally connected to the signal cable to attach the signal cable to the support cable at the points.

20. The seismic cable of claim 19, wherein the arms are at least one of rigid and semi-rigid arms.

21. The seismic cable of claim 19, wherein the arms are mechanically fixed by a plurality of clamps.

22. The seismic cable of claim 19, wherein the arms are rotationally connected by a bearing.

23. The seismic cable of claim 19, further comprising a plurality of stops restraining movement of the rotational connection along the length of the signal cable.

24. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to and distributed along the signal cable and by which the support cable and the signal cable are joined.

25. The seismic cable of 24, wherein the support cable passes through a groove in the sensor modules.

26. The seismic cable of claim 1, wherein each of the sensor modules comprises a housing defining a groove therethrough through which the support cable runs.

27. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by a plurality of elastic devices.

28. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by freely moving through the groove relative to the sensor module.

29. A method for assembling a seismic cable, comprising attaching a support cable to a signal cable at a plurality of points spaced along the length thereof.

30. The method of claim 29, wherein attaching the support cable to the signal cable includes mechanically connecting an electronics module to the support cable and electrically connecting the electronics module to the signal cable.

31. The method of claim 29, wherein attaching the support cable to the signal cable includes zipping the signal cable to the support cable at the points.

32. The method of claim 29, wherein attaching the support cable to the signal cable includes separating the support cable and the signal cable between the points.

33. The method of claim 32, wherein separating the support cable and the signal cable includes pulling a rip-cord.

34. The method of claim 29, wherein attaching the support cable to the sensor includes mechanically affixing at least one of a rigid and a semi-rigid arm to the support cable and rotationally connecting the respective rigid or semi-rigid arm to the signal cable at each of the points.

35. The method of claim 29, wherein attaching the support cable to the signal cable includes connecting the support cable to the signal cable by a plurality of sensor modules.

ABSTRACT

MULTI-PART SEISMIC CABLE

A seismic cable and a method for assembling such a seismic cable are disclosed. The seismic cable includes a support cable and a signal cable attached to the support cable at a plurality of points spaced along the length of the signal cable. The seismic cable also includes at least one sensor module disposed on the signal cable. The method includes attaching a support cable to a signal cable at a plurality of points spaced along the length thereof.

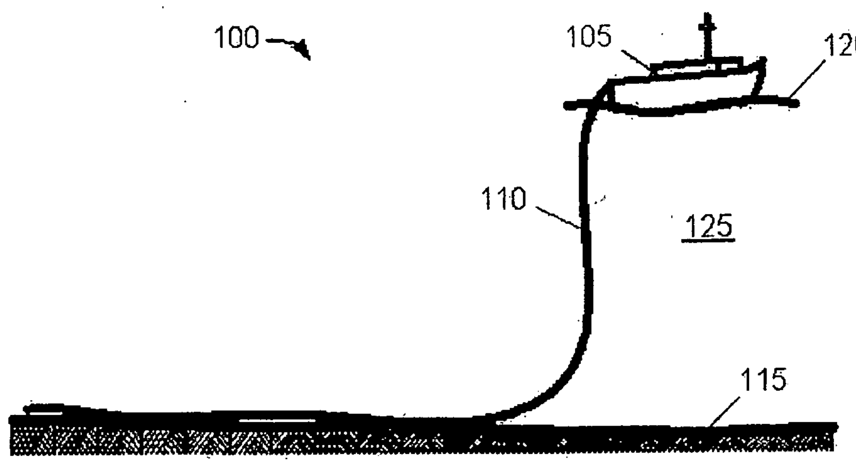

Figure 1

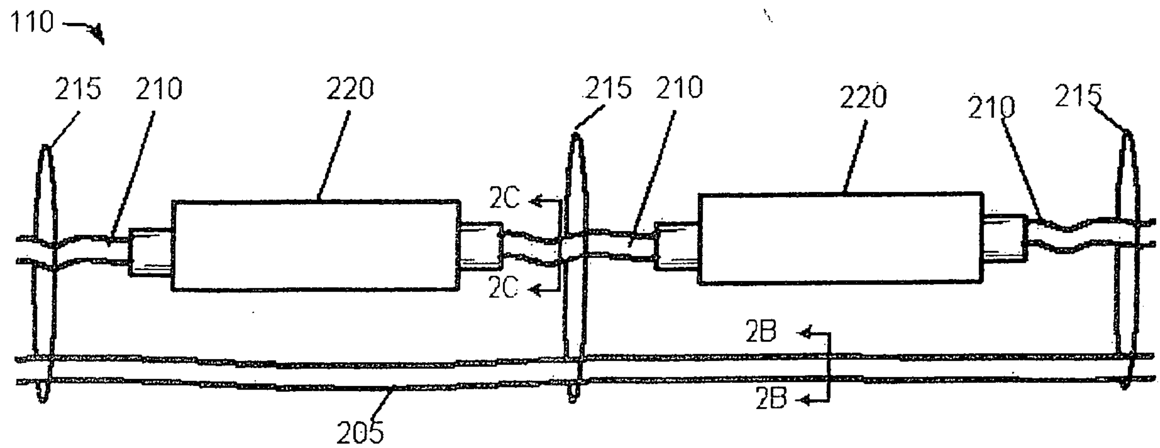

Figure 2A

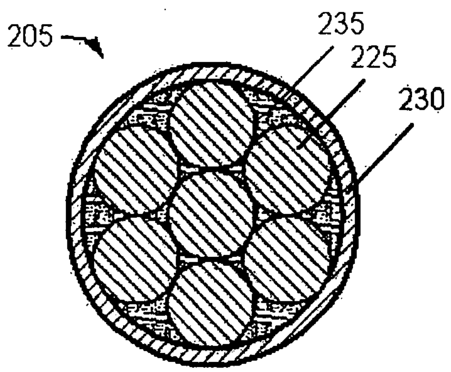

Figure 2B

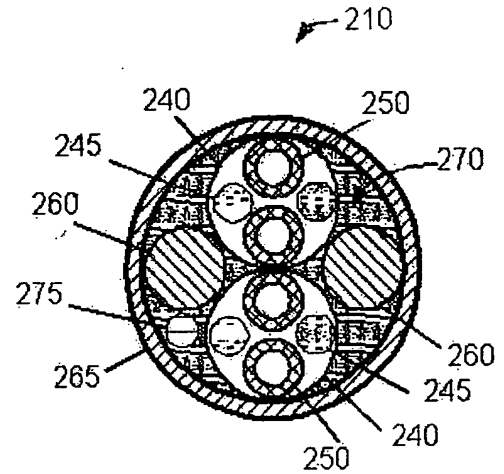

Figure 2C

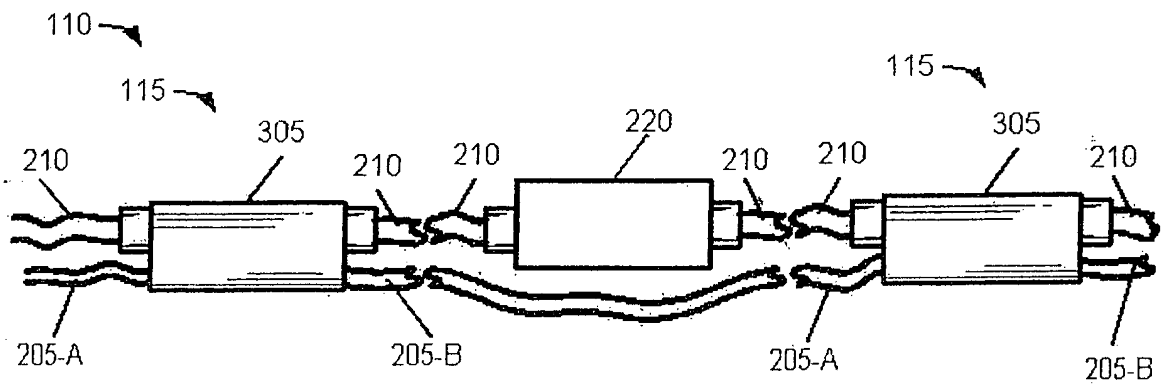

Figure 3

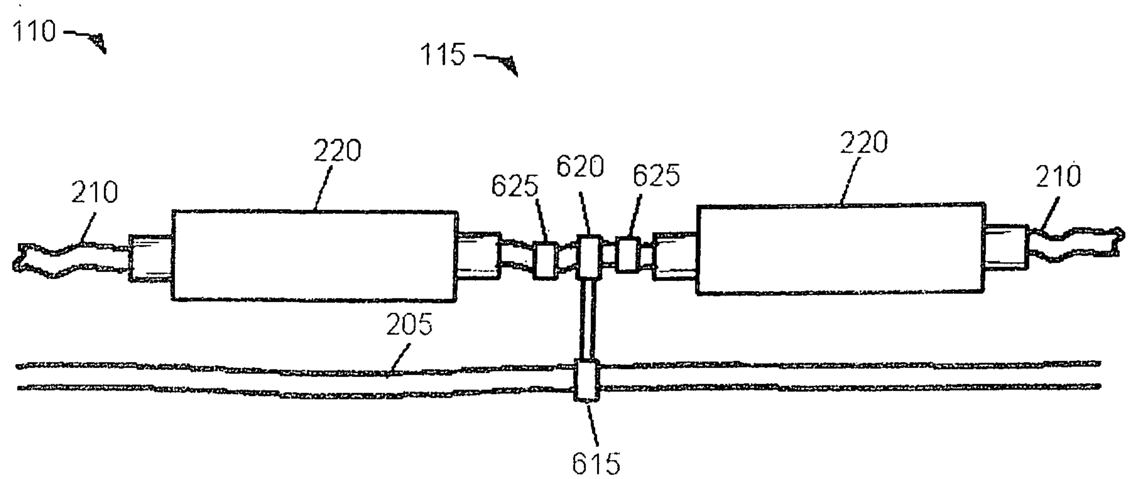

Figure 6

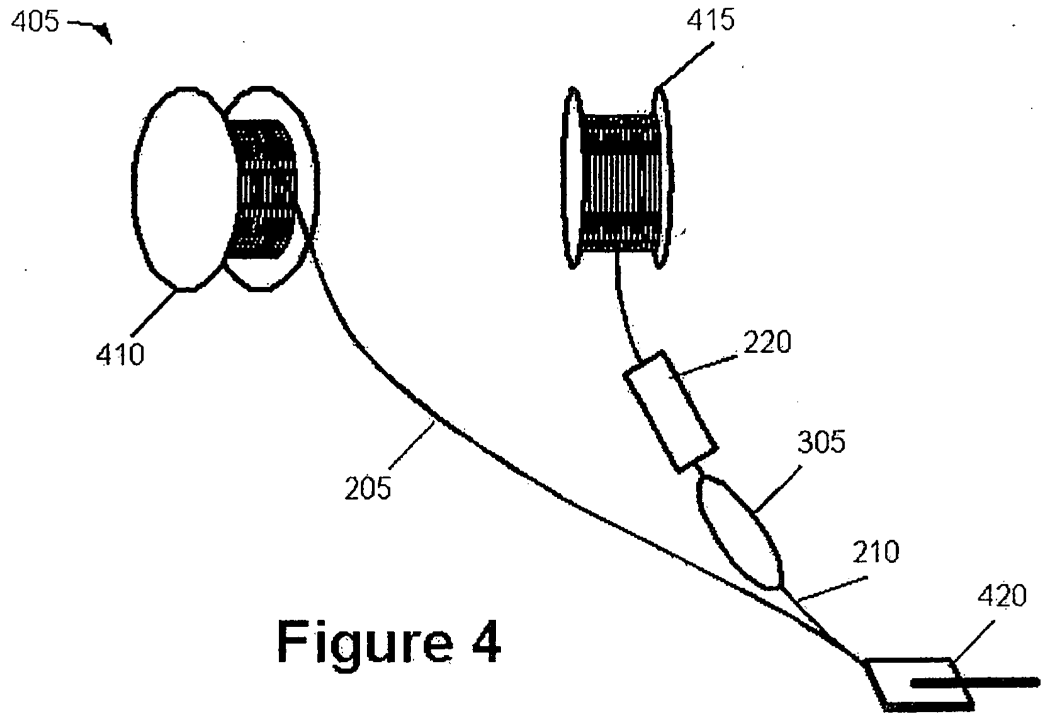

Figure 4

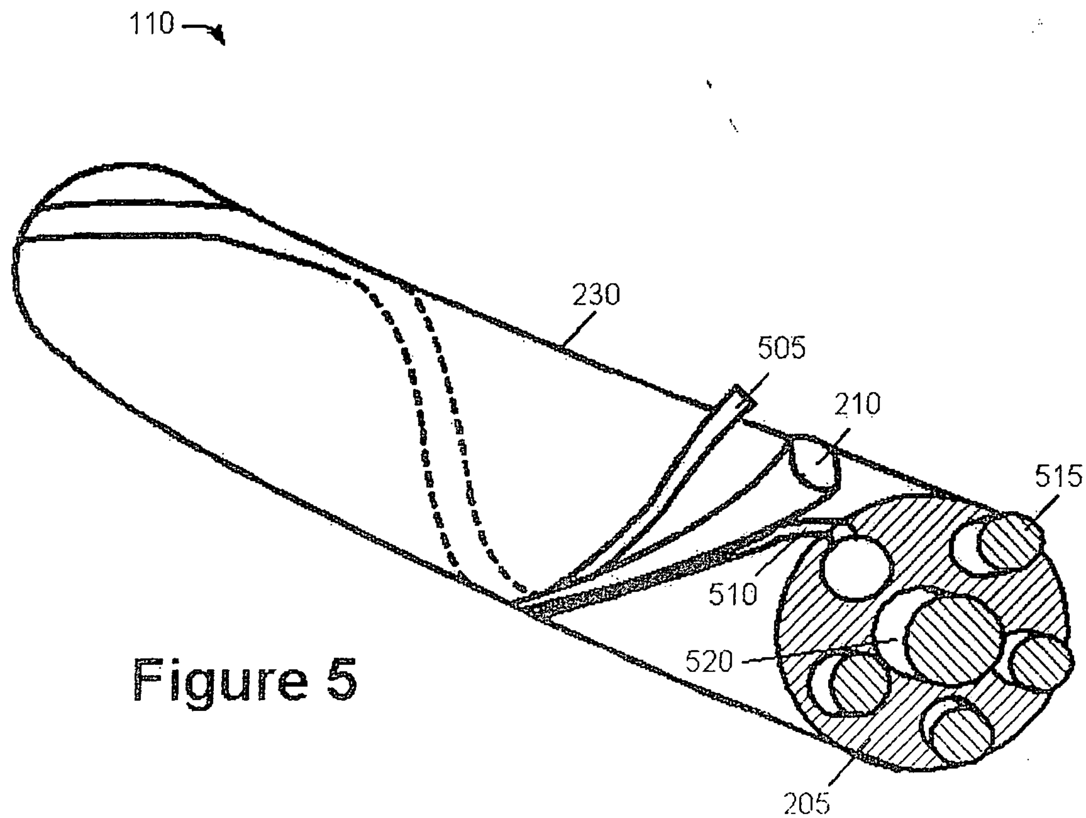

Figure 5

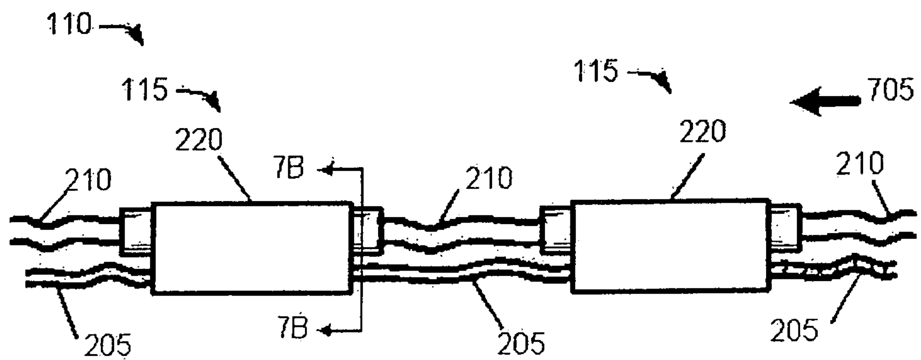

Figure 7A

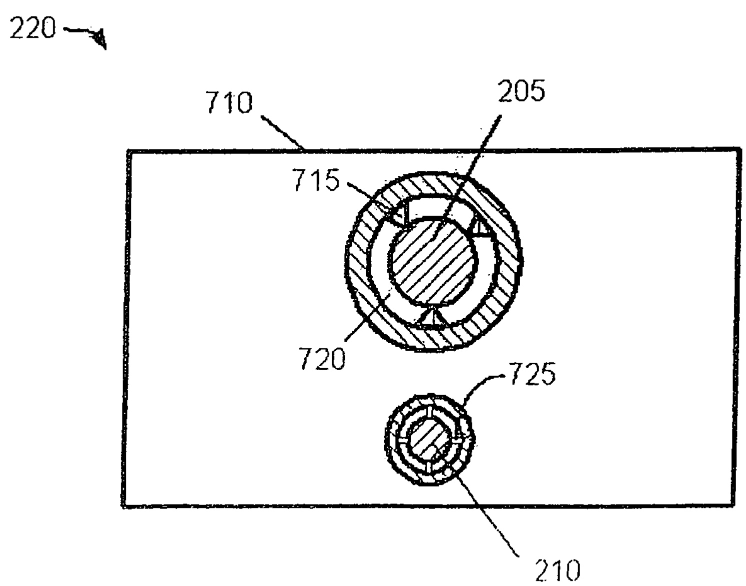

Figure 7B

PATENT COOPERATION TRE[ATY]

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

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PCT

To:

SUCKLING, Andrew
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GRANDE BRETAGNE

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of mailing *(day/month/year)*	15.10.2004
Applicant's or agent's file reference AMS.P52316WO	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP 03/50702	07.10.2003	12.10.2002

Applicant
WESTERNGECO SEISMIC HOLDINGS LIMITED et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

The applicant's attention is drawn to Article 33(5), which provides that the criteria of novelty, inventive step and industrial applicability described in Article 33(2) to (4) merely serve the purposes of international preliminary examination and that "any Contracting State may apply additional or different criteria for the purposes of deciding whether, in that State, the claimed inventions is patentable or not" (see also Article 27(5)). Such additional criteria may relate, for example, to exemptions from patentability, requirements for enabling disclosure, clarity and support for the claims.

Name and mailing address of the international preliminary examining authority:	Authorized Officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Choulouilidou, C Tel. +49 89 2399-2257

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference AMS.P52316WO	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/EP 03/50702	International filing date *(day/month/year)* 07.10.2003	Priority date *(day/month/year)* 12.10.2002
International Patent Classification (IPC) or both national classification and IPC G01V1/38		
Applicant WESTERNGECO SEISMIC HOLDINGS LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 5 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
15.04.2004	15.10.2004
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Schneiderbauer, K Telephone No. +49 89 2399-7613

Form PCT/IPEA/409 (Cover Sheet) (January 2004)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP 03/50702

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1-17 as originally filed

Claims, Numbers

1-35 received on 24.09.2004 with letter of 24.09.2004

Drawings, Sheets

1/4-4/4 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:
   - ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1
	No:	Claims	29
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-35
Industrial applicability (IA)	Yes:	Claims	1-35
	No:	Claims	

2. Citations and explanations

   see separate sheet

1.) **Reference** is made to the following documents:

D1: US-A-2 923 916 (WOODWORTH JOHN H.) 2 February 1960 (1960-02-02)
D2: US-A-3 372 368 (DALE JOHN R ET AL) 5 March 1968 (1968-03-05)
D3: US-A-4 398 276 (KRUPPENBACH JOHN A) 9 August 1983 (1983-08-09)
D4: US-A-4 884 249 (SNOOK CLIVE T) 28 November 1989 (1989-11-28)

2.) **Technical field**: seismic streamers

3.) Novelty (Art.33(1),(2) PCT) and inventive step (Art.33(1),(3) PCT):

3.1) The present application does not meet the requirements of **Article 33(1),(3) PCT**, because the subject-matter of claim 1 is not inventive over D4.

D4 discloses a seismic cable system comprising a tubular shaped elongated and flexible support structure (D4; ref.8 in fig.2; col.3, li.20,21) which supports an active electronic cable 9 (D4; col.3, li.18,19). Cable 9 is equipped with sensors. The active cable 9 (signal cable) is attached to the support cable at a plurality of points spaced along the length of the signal cable (D4; fig.2, col.3, li.42-55).
D4 does not clearly state if reference 13 in fig.2 indicates the means for reception of seismic signals (see also D4; col.2, li.6,7) which in fact would render D4 even novelty destroying over claim 1.
However, even if taking reference 13 not into consideration, it is clear to the skilled person that disposing the sensor moduls substantially at a predetermined location along the length of the seismic cable is state of the art in marine seismics when operating with streamers.
Therefore, the subject-matter of claim 1 cannot be considered as being inventive over the prior art as taught in D4.

3.2) The subject-matter of independent claim 29 is not new over the prior art as disclosed in D4.
D4 discloses a method for assembling a seismic cable, comprising: attaching a support cable (D4; ref.8) to a signal cable (D4; ref.9) at a plurality of points spaced along the length thereof (D4; fig.2).

3.3) The subject-matter of independent claim 29 is also not new with regard to the prior

art as disclosed in D1 and D2 (s. cited passages in the ISR), nor is it considered to be inventive over the prior art as disclosed in D3 (s. cited passages of the ISR). The subject-matter of claim 1 differs from D3 in that a support cable is used and not only a support wire which has the additional advantage of making the system more flexible and efficient. It is clear to the skilled person, also in the light of documents D1 or D2, that such a cable can easily be employed instead of a simple wire in order to arrive at such an advantage. Using a cable instead of a wire does therefore not constitute an inventive step.

3.4) The subject matters of dependent claims 6-8,11-14,16,24,27,30,32 and 35 are not inventive: they can be found in D1, D2 or D3 - **Art.33 (1),(3) PCT** (s. also the cited passages and figures in the ISR).

3.5) The subject-matters of dependent claims 2-5, 9,10, 15, 17-23, 25,26,28, 31, 33 and 34 are not considered to be inventive (**Art. 33(1),(3) PCT**). They appear to be a matter of normal design procedure in order to build a seismic cable system comprising a signal cable (with sensor devices) supported by a support cable.

4.) **Industrial applicability (Art.33(1),(4) PCT)**:
Beyond any doubt the invention, as defined in claims 1-35 is industrially applicable.

CLAIMS

1. A seismic cable, comprising:

a support cable; and

at least one sensor module disposed on a signal cable, the signal cable being attached to the support cable at a plurality of points spaced along the length of the signal cable whereby the or each sensor module is disposed substantially at a predetermined location along the length of the seismic cable.

2. The seismic cable of claim 1, further comprising a first sheath enclosing the support cable and the signal cable.

3. The seismic cable of claim 2, wherein the first sheath comprises at least one of is a skin, a jacket or an extrusion matrix.

4. The seismic cable of claim 1, wherein the support cable includes a plurality of strengthening members.

5. The seismic cable of claim 4, wherein the strengthening members are cabled by a second sheath.

6. The seismic cable of claim 1, wherein the support cable includes at least one of a signal lead and a power lead.

7. The seismic cable of claim 6, further comprising an electronics module powered over the power lead and capable of transmitting data over the signal lead.

8. The seismic cable of claim 7, wherein the support cable is sectioned.

9. The seismic cable of claim 1, wherein the signal cable includes a plurality of leads cabled by a third sheath.

10. The seismic cable of claim 1, wherein the signal cable includes at least one strengthening member.

11. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to the signal cable.

12. The seismic cable of claim 1, wherein the sensor modules transmit data and receive power over the signal cable.

13. The seismic cable of claim 1, further comprising:

a plurality of sensor modules electrically connected to and distributed along the signal cable; and

a plurality of electronics modules by which the signal cable is attached to the support cable at the points.

14. The seismic cable of claim 1, wherein the electronics modules are electrically connected to the signal cable at the points and mechanically connected to the support cable.

15. The seismic cable of claim 1, wherein the signal cable is attached to the support cable by a zipper mechanism.

16 The seismic cable of claim 1, wherein the plurality of points are spaced along the length of the signal cable in proportion to a length of the sensor module.

17. The seismic cable of claim 16, wherein the plurality of points are positioned between adjacent sensor modules

18. The seismic cable of claim 16, wherein the separations are created by pulling a rip cord fabricated in the seismic cable to detach the signal cable from the support cable.

19. The seismic cable of claim 1, further comprising a plurality of arms mechanically affixed to the support cable and rotationally connected to the signal cable to attach the signal cable to the support cable at the points.

20. The seismic cable of claim 19, wherein the arms are at least one of rigid and semi-rigid arms.

21. The seismic cable of claim 19, wherein the arms are mechanically fixed by a plurality of clamps.

22. The seismic cable of claim 19, wherein the arms are rotationally connected by a bearing.

23. The seismic cable of claim 19, further comprising a plurality of stops restraining movement of the rotational connection along the length of the signal cable.

24. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to and distributed along the signal cable and by which the support cable and the signal cable are joined.

25. The seismic cable of 24, wherein the support cable passes through a groove in the sensor modules.

26. The seismic cable of claim 1, wherein each of the sensor modules comprises a housing defining a groove therethrough through which the support cable runs.

27. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by a plurality of elastic devices.

28. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by freely moving through the groove relative to the sensor module.

29. A method for assembling a seismic cable, comprising attaching a support cable to a signal cable at a plurality of points spaced along the length thereof.

30. The method of claim 29, wherein attaching the support cable to the signal cable includes mechanically connecting an electronics module to the support cable and electrically connecting the electronics module to the signal cable.

31. The method of claim 29, wherein attaching the support cable to the signal cable includes zipping the signal cable to the support cable at the points.

32. The method of claim 29, wherein attaching the support cable to the signal cable includes separating the support cable and the signal cable between the points.

33. The method of claim 32, wherein separating the support cable and the signal cable includes pulling a rip-cord.

34. The method of claim 29, wherein attaching the support cable to the sensor includes mechanically affixing at least one of a rigid and a semi-rigid arm to the support cable and rotationally connecting the respective rigid or semi-rigid arm to the signal cable at each of the points.

35. The method of claim 29, wherein attaching the support cable to the signal cable includes connecting the support cable to the signal cable by a plurality of sensor modules.

R

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

SUCKLING, Andrew
MARKS & CLERK
4220 Nash Court
Oxford Business Park South
Oxford OX4 2RU
GRANDE BRETAGNE

RECEIVED
- 1
MAR

PCT

WRITTEN OPINION

Written Opn

(day/mo...

Applicant's or agent's file reference AMS.P52316WO	REPLY DUE	within 4 mon... from the above date of mailing
International application No. PCT/EP 03/50702	International filing date *(day/month/year)* 07.10.2003	Priority date *(day/month/year)* 12.10.2002
International Patent Classification (IPC) or both national classification and IPC G01V1/38		
Applicant WESTERNGECO SEISMIC HOLDINGS LIMITED et al.		

1. This written opinion is the **first** drawn up by this International Preliminary Examining Authority.

2. This opinion contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

   When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).

   How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

   Also: For an additional opportunity to submit amendments, see Rule 66.4. For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4 bis. For an informal communication with the examiner, see Rule 66.6.

   If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: 12.02.2005

Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Schneiderbauer, K Formalities officer (incl. extension of time limits) Püschel, S Telephone No. +49 89 2399-5812

WRITTEN OPINION International application No. PCT/EP 03/50702

I. Basis of the opinion

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed")*:

Description, Pages

1-17 as originally filed

Claims, Numbers

1-35 as originally filed

Drawings, Sheets

1/4-4/4 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:
   - ☐ the drawings, sheets:

5. ☐ This opinion has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

6. Additional observations, if necessary:

WRITTEN OPINION International application No. PCT/EP 03/50702

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1(no), 29 (no)
Inventive step (IS)	Claims	
Industrial applicability (IA)	Claims	all claims (yes)

2. Citations and explanations

see separate sheet

The examination is being carried out on the **following application documents**:

Description, pages:
1-17 as originally filed
Claims, No.:
1-35 as originally filed
Drawings, sheets:
1/4-4/4 as originally filed

Reference is made to the following documents:

D1: US-A-2923916 (Woodworth)	02-02-1960
D2: U-A-3372368 (Dale)	05-03-1968
D3: US-A-4398276 (Kruppenbach)	09-08-1983
D4: US-A-4884249 (Snook)	28-11-1989
D5: US-A-4313392 (Guenther)	02-021982

1.) The present application does not meet the requirements of **Article 33(1),(2) PCT**, because the subject-matters of claim 1 and the corresponding method claim 29 are not new.

Each of the documents D1 and D2 disclose a seismic cable comprising:
- a support cable (D1: fig.3,4, ref.11; D2: tension cable, ref.21 in fig.1)
- a signal cable (D1: fig.3,4, ref.20; D2: streamers 29, 30 and 31 in fig.1) attached to the support cable at a plurality of points spaced along the length of the signal cable (D1: fig.4,5, ref.31,33; D2: streamers 29-31 are attached at a plurality of points to the cable 21 as can be seen from fig.1) and
- at least one sensor module disposed on the signal cable (D1: seismometers 13b, 13c etc.; D2: transducers 24-27)

With this construction the transducers are maintained free from bending stresses when deployed from or rolled upon the drum (s.also D1; col.2, li.30-34).

2.) The present application does not meet the requirements of **Article 33(1),(3) PCT**, because the subject-matters of claim 1 and the corresponding method claim 29 are not inventive over D3 and also not inventive over D4.
D3 discloses a seismic cable (the whole assembly of figure 2, ref.14, 22, 30) comprising:

- a support line (fig.2, ref.30; col.3, li.32, 33)
- a signal cable (fig.2, ref.14) attached to the support cable at a plurality of points spaced along the length of the signal cable (by ring members 22 in fig.2) and
- at least one sensor module disposed on the signal cable (geophones 20 in fig.2)

The subject-matter of claim 1 differs from D3 in that a support cable is used and not only a support wire which has the additional advantage of making the system more flexible and efficient. It is clear to the skilled person, also in the light of documents D1 or D2, that such a cable can easily be employed instead of a simple wire in order to arrive at such an advantage. Using a cable instead of a wire does therefore not constitute an inventive step.
For the same reasons the subject-matters of claims 1 and 29 are also not considered to be inventive over D4 which discloses a seismic cable system comprising a support structure (D4; ref.8 in fig.2: a tubular shaped flexible member; col.3, li.20,21) which supports a cable 9. Cable 9 is equipped with sensors 13 (D4; col.3, li.14-24; col.3, li.42-55).

3.) The subject matters of dependent claims 6-8,11-14,16,24,27,30,32 and 35 are not new - **Art.33 (1),(2) PCT** (s. also the cited passages and figures in ISR).

4.) The subject-matters of dependent claims 2-5, 9,10, 15, 17-23, 25,26,28, 33 and 34 are not considered to be inventive Art. 33(1),(3) PCT). They appear to be a matter of normal design procedure in order to build a seismic cable system comprising a signal cable (with sensor devices) supported by a support cable. These subject-matters would be easily included in D1 by the skilled person and do therefore not involve an inventive step (**Art.33(1),(3) PCT**).

5.) Should the applicant nevertheless regard some particular matter as patentable, a new set of independent claims should be filed. When drafting a new set of claims the applicant should bear the conciseness requirements of Art.6 PCT (only one independent claim in each category) and the unity requirements of Rule 13.1 PCT in

mind. The applicant should also indicate in the letter of reply the difference of the subject-matter of the new claim vis-à-vis the state of the art and the significance thereof.

6.) Remark: D5 could also be used in the further examination. D5 discloses a seismic cable comprising a chain 30 which is used to deploy and retrieve a signal cable 50 to which a plurality of sources are attached. Cable 50 is fixed at a plurality of points to chain 30. Therefore D5 could also be used in the assessment of inventiveness of independent claims 1 and 29.

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D-80928
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Germany

your ref PCT/EP 03/50702

our ref AMS.P52316WO

date 24 September 2004

Facsimile

Dear Sirs

PCT Application PCT/EP 03/50702
WesternGeco Seismic Holdings Limited et al

In response to the first written opinion on the above application, I file herewith a set of amended claims 1 – 35 to replace the current claims.

Claim 1 has been amended to specify that the or each sensor module is disposed at a respective pre-determined location along the seismic cable. The amendment is supported by, for example, the embodiment of figure 2A. The seismic cable of figure 2A comprises the support cable 205 and the signal cable 210, which are attached to one another at a plurality of points 215 along their length. The signal cable is constrained, by its attachment at the points 215 to the support cable, to extend generally parallel to the support cable. The position of each sensor module 220 along the length of the support cable 205 – and thus its position along the length of the seismic cable 110 - is therefore substantially fixed. Little or no relative movement between the sensor module 220 and the support cable 205, in a direction parallel (or perpendicular) to the support cable, is possible.

It is submitted that the amended claim 1 is novel and inventive over the documents cited in the written opinion.

D1 does not disclose a seismic cable in which a signal cable is attached to a support cable. Instead, in D1 the transducer 13b is attached to the "main cable 11", and the cable 20 is attached to the transducer 13b. There is no disclosure or suggestion in D1 of directly attaching the cable 20 to the main cable 11 in the manner shown in, for example, figure 2A of the present application.

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As far as inventive step over D1 is concerned, the arrangement shown in figure 4 of D1 will lead to acoustic coupling between the main cable 11 and the transducer 13b. While the resilient secondary support 31 may to some extent reduce the coupling between the main cable and the transducer, the resilient secondary support disclosed in D1 will still allow significant coupling to occur. In contrast, the arrangement of the present invention in which the signal cable is coupled to the support cable at locations between the sensor modules 220, or in which the support cable 205 is coupled direct to the sensor modules via the resilient coupling, shown in figure 7B, provides far better decoupling between the support cable and the sensor modules as stated at page 15, lines 8-10.

D2 relates to a vertical hydrophone array rather than to a seismic cable intended for use in a ocean bottom seismic survey. It shows an arrangement in which a plurality of hydrophones 24, 25, 26, 27 are interconnected by spacer members 28. The spacer members are connected to a "main tension cable member" 21 at a number of discreet tie points. The positions along the main cable at which the sensors are deployed is not constant in D2 - the teaching of D2 is that the hydrophones are able move relative to the main cable 21 in order to form a vertical array. This can be seem by comparing figures 1 and 2 of D2. The amended claim 1 is novel and inventive over D2, since D2 does not disclose placing the hydrophones at a respective pre-determined location along the main tension cable member, and doing this would be contradictory to the teaching of D2. (It should be noted that the arrangement of D2 is unsuitable for use in an ocean bottom survey. Since the hydrophones can move both laterally and radially with respect to the main tension cable member, the positions of the hydrophones when the cable had been deployed on the sea bed would not be known – knowledge of the location of the main tension cable member would not allow the positions of the individual hydrophones to be determined. The uncertainty in the positions of the hydrophones would degrade the reliability of any acquired data.)

In D3 the positions of the geophones 16 are clearly not fixed along the cable. D3 clearly teaches that the sensors 12 are mounted on the line 30 by "ring members", so that each sensor can slide along the line 30.

D4 relates to a towed marine cable in which an "active member" that contains sensors is suspended by ropes 10 from a point buoyancy member 8. Relative movement will be possible between the active member and buoyancy member (for example in rough seas).

Finally, in D5 the seismic sources 13 are not disposed in the signal cable in the manner of the present invention. The seismic sources are suspended from the "core" 50, and this will require the provision of takeouts in the core to enable electrical connections to pass out of the core 50 to each source. The disadvantages set out at page 2, line 14 to page 1, line 2 will occur in D5. D5 does not teach or suggest the provision of a signal cable that is attached to a support cable at points spaced along the length of the signal cable.

It is believed that a favourable IPER can now be issued. If, however, there should be any outstanding objections to patentability I request that a further written opinion is issued.

Yours faithfully
MARKS & CLERK

Dr A.M. Suckling

CLAIMS

1. A seismic cable, comprising:

a support cable; and

at least one sensor module disposed on a signal cable, the signal cable being attached to the support cable at a plurality of points spaced along the length of the signal cable whereby the or each sensor module is disposed substantially at a predetermined location along the length of the seismic cable.

2. The seismic cable of claim 1, further comprising a first sheath enclosing the support cable and the signal cable.

3. The seismic cable of claim 2, wherein the first sheath comprises at least one of is a skin, a jacket or an extrusion matrix.

4. The seismic cable of claim 1, wherein the support cable includes a plurality of strengthening members.

5. The seismic cable of claim 4, wherein the strengthening members are cabled by a second sheath.

6. The seismic cable of claim 1, wherein the support cable includes at least one of a signal lead and a power lead.

7. The seismic cable of claim 6, further comprising an electronics module powered over the power lead and capable of transmitting data over the signal lead.

8. The seismic cable of claim 7, wherein the support cable is sectioned.

9. The seismic cable of claim 1, wherein the signal cable includes a plurality of leads cabled by a third sheath.

10. The seismic cable of claim 1, wherein the signal cable includes at least one strengthening member.

11. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to the signal cable.

12. The seismic cable of claim 1, wherein the sensor modules transmit data and receive power over the signal cable.

13. The seismic cable of claim 1, further comprising:

a plurality of sensor modules electrically connected to and distributed along the signal cable; and

a plurality of electronics modules by which the signal cable is attached to the support cable at the points.

14. The seismic cable of claim 1, wherein the electronics modules are electrically connected to the signal cable at the points and mechanically connected to the support cable.

15. The seismic cable of claim 1, wherein the signal cable is attached to the support cable by a zipper mechanism.

16 The seismic cable of claim 1, wherein the plurality of points are spaced along the length of the signal cable in proportion to a length of the sensor module.

17. The seismic cable of claim 16, wherein the plurality of points are positioned between adjacent sensor modules

18. The seismic cable of claim 16, wherein the separations are created by pulling a rip cord fabricated in the seismic cable to detach the signal cable from the support cable.

19. The seismic cable of claim 1, further comprising a plurality of arms mechanically affixed to the support cable and rotationally connected to the signal cable to attach the signal cable to the support cable at the points.

20. The seismic cable of claim 19, wherein the arms are at least one of rigid and semi-rigid arms.

21. The seismic cable of claim 19, wherein the arms are mechanically fixed by a plurality of clamps.

22. The seismic cable of claim 19, wherein the arms are rotationally connected by a bearing.

23. The seismic cable of claim 19, further comprising a plurality of stops restraining movement of the rotational connection along the length of the signal cable.

24. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to and distributed along the signal cable and by which the support cable and the signal cable are joined.

25. The seismic cable of 24, wherein the support cable passes through a groove in the sensor modules.

26. The seismic cable of claim 1, wherein each of the sensor modules comprises a housing defining a groove therethrough through which the support cable runs.

27. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by a plurality of elastic devices.

28. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by freely moving through the groove relative to the sensor module.

29. A method for assembling a seismic cable, comprising attaching a support cable to a signal cable at a plurality of points spaced along the length thereof.

30. The method of claim 29, wherein attaching the support cable to the signal cable includes mechanically connecting an electronics module to the support cable and electrically connecting the electronics module to the signal cable.

31. The method of claim 29, wherein attaching the support cable to the signal cable includes zipping the signal cable to the support cable at the points.

32. The method of claim 29, wherein attaching the support cable to the signal cable includes separating the support cable and the signal cable between the points.

33. The method of claim 32, wherein separating the support cable and the signal cable includes pulling a rip-cord.

34. The method of claim 29, wherein attaching the support cable to the sensor includes mechanically affixing at least one of a rigid and a semi-rigid arm to the support cable and rotationally connecting the respective rigid or semi-rigid arm to the signal cable at each of the points.

35. The method of claim 29, wherein attaching the support cable to the signal cable includes connecting the support cable to the signal cable by a plurality of sensor modules.

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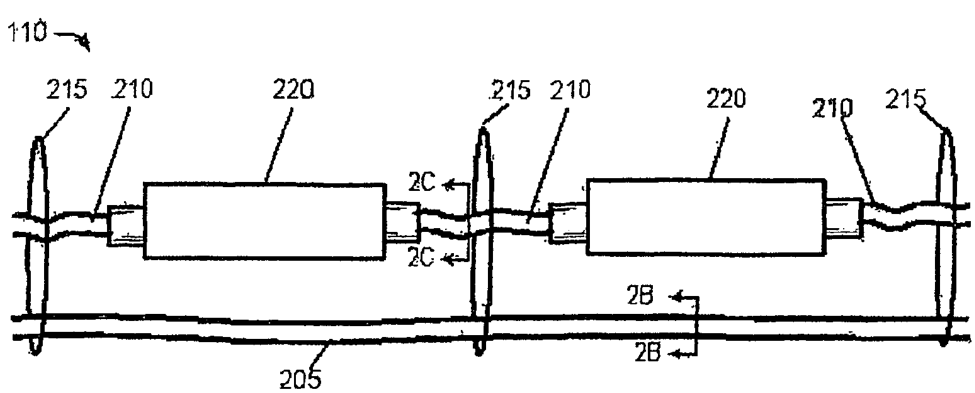

(57) Abstract: A seismic cable (110) and a method for assembling such a seismic cable are disclosed. The seismic cable (110) includes a support cable (205) and a signal cable (210) attached to the support cable (205) at a plurality of points spaced along the length of the signal cable (210). The seismic cable (110) also includes at least one sensor module (220) disposed on the signal cable (210). The method includes attaching a support cable (205) to a signal cable (210) at a plurality of points spaced along the length thereof.

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MULTI-PART SEISMIC CABLE

1. FIELD OF THE INVENTION

This invention relates generally to seismic cable systems, and, more particularly, to a robust and reliable seismic cable system.

2. DESCRIPTION OF THE RELATED ART

Subsurface hydrocarbon accumulations are increasingly found in geologically complex areas. The ability to conduct accurate seismic surveys may help improve the discovery rates and even the production of such accumulations. Seismic surveying is a method of stimulating a geological subsurface formation with, *e.g.*, electrical, magnetic, and/or acoustic signals to acquire seismic data about the formation. From this data, one can predict tell whether the formation contains hydrocarbon deposits and, if so, where.

One type of seismic survey is generally referred to as a "marine" survey because it is typically conducted at sea, although this is not necessarily always the case. During marine seismic surveys, seabed seismic cable systems are deployed to the bed of a sea, lake, river, or marsh. The water depth may range from several thousand meters up to the water/land transition zone. Water currents of considerable speed may pass over the cable system and create instability and deterioration of the seismic data quality.

Seabed seismic cable systems generally are designed to meet two conflicting goals. First, the cable system must be robust and resistant to damage. For example, the cable

system must survive and operate at great water depth. Also, the cable system may be roughly handled during deployment and retrieval. Second, the cable system should be sensitive to acoustic vibrations and not compromise the quality of data recorded by the sensor units.

Although there are several types of seabed seismic cables, there are generalities in construction. A seabed seismic cable includes three main elements: stress members, leads, and a sheath. One or several stress members take the tension that can be applied to the seabed seismic cable during deployment and retrieval operations to protect other elements of the cable. The leads, which may be electrical or optical, transmit power and/or data, in analog or digital format, along the cable for collection and processing, *e.g.*, on a survey vessel. The sheath is a skin, jacket or extrusion matrix protecting the seabed seismic cable against, notably, water ingress.

One type of seabed cable is known as an "ocean bottom cable" ("OBC"), and is typically equipped with "takeouts." A full length of conventional OBC is seismic built, the jacket is then opened at the location were the sensors are located, and leads are extracted from the cable to form a take-out and connected to the sensors. The sensors are then attached to the cable.

These types of cable are prone to water intrusion, electrical leakage, and wire kinking, as the take-outs are submitted to a high level of strain during cable handling. These cables usually have an asymmetric cross-section at the sensors, and the response will change depending on how the sensors rest on the seafloor. These types of cables also expose the seismic receivers and the takeouts to a number potentially damaging obstacles on the seabed, thereby reducing the reliability of the collected data. Furthermore, because the takeouts are

extracted from the cable and not a separate component, the entire cable may need to be replaced if the takeouts are damaged, which can be expensive and time-consuming.

Improvements to this type of apparatus appear in U.S. Patent No. 6,294,727 to Orlean, which provides for an "overmolding" of the cable and the sensor units. Improvements also appear in U.S. Patent and 6,333,898 to Knudsen *et al.* and U.S. Patent No. 6,041,282 to Wardeberg *et al.* (collective referred as "steel armored cables"), which provide for a preparation of steel armored cable without takeouts. However, the Orlean and steel armored cables still suffer from the drawbacks mentioned above, including water intrusion, electrical leakage, and wire-kinking. Furthermore, the Orlean and steel armored cables usually suffer from the asymmetric cross-section at the sensor units.

Another type of seabed seismic cable system is commonly referred to as a logging type cable. Logging type cables typically have a full electrical/optical termination at each sensor unit, resulting in a high number of connection points. The high number of connection points negatively impacts the cable's reliability. Furthermore, the increased number of terminations makes the sensor unit large and heavy, which negatively impacts data quality.

Yet another type of seabed seismic cable system comprises conventional cables with sensor units integrated inside a protective cable jacket. One variation is known as a "streamer type" cable. The streamer type cable is an evolution of a towed seismic streamer for deployment on the seabed. The streamer type cable comprises spacers, sensor units, and a filler, which usually is oil. The streamer type cable has a constant diameter and therefore occupies a large volume when stored. An alternative variation is known as a "solid cable." One example of the solid cable is shown in U.S. Patent No. 6,333,897 to Knudsen *et al.*,

which can be produced with a constant diameter or a variable diameter. Both the constant diameter and the variable diameter cables pose potentially serious drawbacks. The cable with a constant diameter is extremely large, heavy and stiff. The cable with a variable diameter is difficult to manufacture.

The present invention is directed to overcoming, or at least reducing the effects of, one or more of the problems set forth above.

SUMMARY OF THE INVENTION

The invention comprises a seismic cable and a method for assembling such a seismic cable. The apparatus comprises seismic cable including a support cable and a signal cable attached to the support cable at a plurality of points spaced along the length of the signal cable. The seismic cable also includes at least one sensor module disposed on the signal cable. The method includes attaching a support cable to a signal cable at a plurality of points spaced along the length thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify like elements, and in which:

FIG. 1 illustrates a seismic survey vessel from which a seismic cable constructed and operated in accordance with the present invention is deployed;

FIG. 2A to FIG. 2C illustrate a first embodiment of the seismic cable of FIG. 1 in accordance with the present invention wherein:

- FIG. 2A illustrates in a partially sectioned view of the seismic cable of FIG. 1, in accordance with one embodiment of the present invention;
- FIG. 2B illustrates the support cable of FIG. 2A cross-sectioned along line 2B-2B in FIG. 2A; and
- FIG. 2C illustrates the signal cable of FIG. 2A cross-sectioned along line 2C-2C in FIG. 2A;

FIG. 3 illustrates a partial view of the seismic cable of FIG. 1, in accordance with one particular embodiment of the present invention in which the support and signal cables are attached by the electronics modules;

FIG. 4 illustrates a storage and deployment mechanism for the seismic cable of FIG. 1, in accordance with a second embodiment alternative to that in FIG. 3 in which the support and signal cables are joined by a zipper mechanism;

FIG. 5 illustrates a partial, perspective, cross-sectioned view of the seismic cable of FIG. 1, in accordance with a third embodiment alternative to those in FIG. 3 and in FIG. 4 in which the support and signal cables are fabricated together and then separated by a rip-cord;

FIG. 6 illustrates a partial plan view of the seismic cable of FIG. 1, in accordance with a fourth embodiment in which the support cable and the signal cable are attached by a rigid arm; and

FIG. 7A and FIG. 7B illustrate a fifth embodiment in a side, plan view and in an end, partially sectioned view (along line 7B-7B), respectively, which the support and signal cables are attached by the housings of the sensor modules.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

FIG. 1 illustrates a seismic survey system 100 in which a seismic survey vessel 105 has deployed a seismic cable 110 to the bed 115 from the surface 120 of a body of water 125. In the illustrated embodiment, the body of water 125 is part of an ocean. Consequently, the

bed 115 is a seabed (or, ocean floor). However, the invention is not so limited, as the invention may used for surveys conducted in fresh and brackish waters.

FIG. 2A illustrates a seismic cable 110 in accordance with one embodiment of the present invention. The seismic cable 110 comprises a support cable 205 and a signal cable 210 attached to the support cable 205 at a plurality of points 215 spaced along the length thereof. In the illustrated embodiment, the signal cable 210 further comprises a plurality of sensor modules 220, which will be discussed further below. In one embodiment, the spacing of the points 215 is approximately proportional to a length of the sensor modules 220 so that the points 215 are located between each of the sensor modules 220. However, the present invention is not so limited. In alternative embodiments, the points 215 may be located at any desirable location. For example, the points 215 may be located between every other sensor module 220 or between successive pluralities of sensor modules 220. For another example, a plurality of points 215 may be located between each pair of sensor modules 220.

As is shown in **FIG. 2B**, the support cable 205 includes one or more stress members 225 (only one indicated) providing tension to the seismic cable 110. The stress members 225 may be any type of stress member known to the art for handling tension in seismic cables. Examples of suitable stress members 225 include, but are not limited to, steel wire and utility cable. If more than one stress member 225 is employed, as in the illustrated embodiment, the stress members 225 may be cabled together in any suitable fashion known to the art. For instance, in the illustrated embodiment, the stress members 225 are jacketed together, *i.e.*, cabled together by enclosure in a jacket 230. Furthermore, in some embodiments, the support cable 205 may be filled with a filler 235 to, *e.g.*, help protect against water intrusion. The filler 235 may be of any suitable type known to the art.

As is shown in **FIG. 2C**, the signal cable 210 comprises, *inter alia*, a plurality of signal leads 240, and, in the illustrated embodiment, one or more power leads 260. The signal leads 240 may include electrical leads 245 such as a twisted wire pair of leads, a coaxial cable, and the like. The signal lead 240 may also include one or more optical fibers 250. As with the support cable 205, these elements may be cabled together in any suitable fashion known to the art. For instance, in the illustrated embodiment, the leads 240, 245, 250, 260 are jacketed together, *i.e.*, cabled together by enclosure in a jacket 265. Furthermore, in some embodiments, the signal cable 210 may be filled with a filler 270 to, *e.g.*, help protect against water intrusion. The filler 270 may be of any suitable type known to the art. In the illustrated embodiment, the signal cable 210 also includes a stress member 275 for providing extra support on forces exerted against the signal cable 210, although the invention is not so limited. In alternative embodiments, the signal cable 210 may not include the stress member 275 or may include a plurality of stress members 275.

Returning to **FIG. 2A**, the signal cable 210, in the illustrated embodiment, further comprises one or more sensor modules 220. The sensor module 220 includes one or more sensors (not shown). Examples of sensors include, but are not limited to, geophones, accelerometers, hydrophones, tilt meters, and magnetometers.

These sensors generate data in the course of survey operations and transmit that data over the signal cable 210 in a conventional manner. The sensors may include electronics for conditioning the signal and/or digitizing it. The sensor module 220 is typically connected to the signal cable 210 by one or more the sensor leads 240, 245, 250, 260 shown in Figure 2C. Note that the composition of sensors in each sensor module 220 may be the same or may be unique, depending on the implementation. To some degree, the choice of sensors may

influence the number and implementation of the signal and power leads (*e.g.*, the leads 240, 245, 250, 260 in **FIG. 2C**).

The data from the sensors may be transmitted to one or more electronics modules (not shown in **FIG. 2A**) located along the seismic cable 110 or between cable sections. The electronics module is connected to the signal cable the signal cable 210 by one or more of the signal leads (*e.g.*, the signal leads 240, 245, 250, 260 in **FIG. 2C**) of the signal cable. Alternatively, the functionality of the electronics module may reside in one or more of the sensor modules 220 in some alternative embodiments. The electronics module serves as a data transmission and power hub for the sensor modules 220. In one embodiment, the electronics module may comprise a high bandwidth bus capable of transmitting data between other electronics modules and to a computer or other computing device (not shown) on the seismic survey vessel 105 or at a remote location. In an alternative embodiment, the sensor module 220 may be connected to the signal cable 210 by a data bus (not shown). Regardless, one important function of the electronics module is to collect and forward the data generated and transmitted by the sensor modules.

In one embodiment, the sensor module 220 is sufficiently sealed to protect against water intrusion and physical damage. However, in alternative embodiments, the seismic cable 110 may be enclosed by a sheath, or protective outer covering (not shown).. In embodiments wherein the support cable 205 includes leads, the support cable 205 may also be enclosed by a sheath (not shown). The sheath protects sensitive electronics such as the signal cable 210 and sensor module 220 from water intrusion and physical damage. The protective outer covering can be any skin, jacket, or extrusion matrix known in conventional practice.

Although the support cable 205 bypasses the sensor module 220 as illustrated in **FIG. 2A**, in an alternative embodiment, a groove can be provided in the sensor module 220 such that the support cable 205 passes through the sensor module 220 via the groove. The support cable 205 can be acoustically decoupled from the sensor module 220 by one or more acoustic decoupling devices (not shown) between the groove and the support cable 205, such as springs or elastic devices, as will be discussed further below.

As was mentioned above, the signal cable 210 is attached to the support cable 205 at a plurality of points 215, shown generically in **FIG. 2A**. The invention admits wide variation in how this attachment may be accomplished, and may employ virtually any suitable attachment mechanism. **FIG. 3** – **FIG. 6** each illustrate various alternative embodiment employing and implementing different attachment mechanisms. More particularly:

- **FIG. 3** illustrates an embodiment in which the attachment is made through electronics modules 305 being connected to both a signal cable 210 and a support cable 205-A;
- **FIG. 4** illustrates the deployment of an embodiment in which the attachment is made through a zipper mechanism;
- **FIG. 5** illustrates an embodiment in which the support cable 205 and the signal cable 210 are separated after fabrication by a rip-cord 505; and
- **FIG. 6** illustrates an embodiment in which the attachment is made by a rigid arm 610.

Each of these alternative embodiments shall now be discussed more fully in turn.

FIG. 3 illustrates one embodiment of the seismic cable 110, in which an electronics module 305 separating two support cable sections referred in **FIG. 3** as a left support cable

section 205-A and a right support cable section 205-B section. As mentioned, the electronics module 305 is placed at intervals along the seismic cable 110 of **FIG. 1** and **FIG. 2A** and is generally placed between the support cable sections 205-A, 205-B.

As illustrated in **FIG. 3**, the signal cable 210 is directly connected to the electronics module 305. In one embodiment, the left support cable section 205-A terminates on one side of the electronics module 305 and begins anew at the right support cable 205-B at another side of the electronics module 305. In an alternative embodiment, the support cable sections 205-A, 205-B pass through the electronic module 305.

Although not illustrated in **FIG. 3**, it should be appreciated that at least of a portion the support cable sections 205-A, 205-B and signal cable 210 may be connected by some other attachment mechanism in addition to the attachment provided at the sensor module 305. For instance, the embodiment of **FIG. 3** might also employ the rigid or semi-rigid arm 610 in **FIG. 6**, discussed more fully below. Thus, some embodiments might use several different types of attachment mechanisms.

FIG. 4 illustrates an embodiment of the seismic cable 110 in **FIG. 1** alternative to that of **FIG. 3**. A storage and deployment mechanism 405 is shown, which stores a continuous length of support cable 205 in a support cable storage 410 and a continuous length of signal cable 210 in a signal cable storage 415. As mentioned, the sensor module 220 and the electronics module 305 are directly connected to the signal cable 210 and are stored along with the signal cable 210 in the signal cable storage 415. It should be appreciated that although the support cable storage 410 and the signal cable storage 415 are illustrated in a

common "spool" configuration, any method of storing a continuous length of cable known in conventional practice may be used.

The support cable 205 and the signal cable 210 are attached at one end by a zipper mechanism 420. As the support cable 205 is deployed from the support cable storage 410 and signal cable 210 is removed from signal cable storage 415, the zipper mechanism 420 is guided in the direction of the spools 410, 415, thereby automatically attaching the support cable 205 with the signal cable 210. The zipper mechanism 420 can be any mechanism known in the art for automatically clamping two members in a zipping fashion. For example, the zipper mechanism 420 may comprise a plurality of clamps that are individually operated to attach the support cable 205 with the signal cable 210. The plurality of clamps may be located on the support cable 205, the signal cable 210, or both. Another example of the zipper mechanism is a Velcro-based solution. Yet another example of a zipper mechanism is strong thread that attaches the signal cable to the support cable by sowing, wrapping or knitting.

Because the sensor module 220 and the electronics module 305 are attached to the signal cable 210 without tension, the signal cable 210 will be subjected to relatively gentler handling. Furthermore, this embodiment of the seismic cable 110 allows for greater operation depth and easier handling in adverse weather. The design also allows easier and faster replacement of component parts in the seismic cable 110. Still further, because the signal cable 210 and support cable 205 can be stored without tension, less space is needed in the signal cable storage 415 and the support cable storage 410, respectively. One important feature of this arrangement is that the signal cable 210 is handled and stored with virtually no tension. This creates an opportunity for the cable designer to avoid certain conflicting requirements like cable strength vs. unwanted inter-cable acoustic coupling.

Note that, in some embodiments, the electronics module can be carried as part of the support cable 205, as opposed to the signal cable 210. In such an embodiment, the support cable 205 comprises one or more electronics modules 305 (first shown in **FIG. 3**) connected to one or more leads in the support cable 205. The leads may be electrical or optical, depending on their purpose and the particular embodiment. The leads may be for transmitting data and power for the operation of the electronics modules 305. For instance, signal leads (*e.g.* the signal leads 240 shown in Figure 2C) may be used to transmit data from the electronics modules 305 to, *e.g.*, a computing device (not shown) located on the seismic survey vessel 105 (first shown in **FIG. 1**) or at the remote location. Similarly, leads may be employed for transmitting power from the survey vessel 105 to the electronics modules 305.

One example of such a seismic cable 110 is illustrated in **FIG. 5**. The support cable 205 and the signal cable 210 are manufactured together in one continuous unit and substantially enclosed by the protective outer covering 230. The signal cable 210 can be detached over short sections where the sensor modules (not shown in **FIG. 5**) are desired by pulling a rip-cord 505. Detaching the signal cable 210 from the seismic cable 110 leaves an empty groove 510. If the outer covering 230 is comprised of a thermoplastic, the rip-cord 505 can be heated by electrical current, for example, to ease pulling the rip-cord 510. Once the signal cable 210 is detached, it can be terminated and connected to the sensor module 220. The support cable 205, in the embodiment of **FIG. 6**, includes several signal leads 515 (only one indicated) over which control and data signals may be transmitted and a power lead 520 over which the electronic modules 320 may be powered.

FIG. 6 il lustrates an alternative embodiment of the attachment mechanism 215 of FIG. 2A. Aarm 610 separates the support cable 205 from the signal cable 210 at a sufficient distance such that the support cable 205 and the signal cable 210 do not contact during deployment. In alternative embodiments, the arm 610 may be rigid or semi-rigid. A semi-rigid arm 610 will flex along the direction of the signal cable 210 but be rigid in the direction of rotation about the signal cable 210. The arm 610 is attached to the support cable 205 by a clamp 615. The arm 610 should generally be attached loosely to the signal cable 210 such that excess torsion is not introduced into the signal cable 210. For example, as illustrated in FIG. 6, the arm 610 is attached to the signal cable 210 by a bearing 620 that allows the signal cable 210 to rotate freely around the signal cable 210 and move axially between two stop clamps 625.

FIG. 7A and FIG. 7B illustrate another alternative embodiment in which the support cable 205 and the signal cable 210 are attached by the housings of the sensor modules 220 themselves. The view in FIG. 7B is from the direction of the arrow 705 in FIG. 7A and sectioned along the line 7B-7B in FIG. 7A. As was alluded to earlier, the support cable 205 is acoustically decoupled from the housing 710 of the sensor module 220 by a plurality of elastic devices 715 (only one indicated), such as springs, as is shown in FIG. 7B. In some alternative embodiments, the elastic devices 715 may be omitted. Note that a plurality of electrical connections 725 (only one indicated) are conceptually illustrated between the signal cable 210 and the sensor module 220.

The elastic devices 715 are positioned between the support cable 705 and the sensor housing 710 in the groove 720 defined by the sensor housing 710 and through which the support cable 205 runs. Such decoupling techniques are known to the art, and one is more

fully disclosed in International Patent WO0214905, published February 21, 2002, in the name of James Martin, Nicolas Goujon, Frederik Naes, and Rune Voldsbekk.., and entitled "A HOUSING FOR A SEISMIC SENSING ELEMENT AND A SEISMIC SENSOR." However, other techniques may also be employed in alternative embodiments. For instance, some embodiments, the support cable is decoupled from the sensor housing 710 by being permitted to slide freely through the groove 720 relative to the sensor module 220.

The present invention facilitates acoustic decoupling of the sensor modules 220—and, hence, the sensors—from the stress member 205, which is rigid and under tension, and therefore improves the data quality recorded by the system 100. The various embodiments described herein provide a robust cable 110 capable of being subjected to rough handling when the cable 110 is deployed and/or retrieved. The robust cable 110 is further capable of being subjected to great water depth and pressure. Although the cable 110 is substantially robust, the cable 110 delivers higher data quality than previous cables. More particularly, in its various aspects and embodiments, the invention provides the following advantages over the state of the art:

- higher reliability of the connections to the sensor modules 220, as takeouts are eliminated;
- reduced number of connections;
- increased cable strength as terminations of the stress member 205 are eliminated;
- improved sensor-to-ground coupling due to the smaller and lighter sensor module 220;
- more precise data recording independent of how the sensor module 220 rests on the seafloor due to axial symmetry of the cable 110 and sensor module 220;

- mechanical decoupling between the sensor module 220 and the support cable, thus freeing the sensor module 220 from the stresses on the stress member 205 and improving data quality;
- high data quality independent of water depth;
- higher possibility for the same axial symmetry for the cable 110 as for the sensor module 220 and for positioning the sensor module 220 closer to the center of gravity of the sensor module 220—thereby providing consistent and repeatable independent of how the sensor module 220 lies on the seafloor;
- higher modularity of cable construction providing increased reparability, reconfiguration possibilities, improved depth-appropriate assembly, and even the possibility of omitting stress carrying support for shallow water operations;
- easier handling procedures, as the stress member 205 and the signal cable 210 can be separated for storage and shipping; and
- safer handling for components since the sensor module 220 can be stored separately from the stress member 205, thereby reducing danger to the sensor module 220 from tension on the stress member 205.

Note that not all of these advantages will be realized in every embodiment of the invention. Still other advantages may become apparent to those skilled in the art having the benefit of this disclosure.

This concludes the detailed description. The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the

particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

CLAIMS

1. A seismic cable, comprising:

a support cable;

a signal cable attached to the support cable at a plurality of points spaced along the length of the signal cable; and

at least one sensor module disposed on the signal cable.

2. The seismic cable of claim 1, further comprising a first sheath enclosing the support cable and the signal cable.

3. The seismic cable of claim 2, wherein the first sheath comprises at least one of is a skin, a jacket or an extrusion matrix.

4. The seismic cable of claim 1, wherein the support cable includes a plurality of strengthening members.

5. The seismic cable of claim 4, wherein the strengthening members are cabled by a second sheath.

6. The seismic cable of claim 1, wherein the support cable includes at least one of a signal lead and a power lead.

7. The seismic cable of claim 6, further comprising an electronics module powered over the power lead and capable of transmitting data over the signal lead.

8. The seismic cable of claim 7, wherein the support cable is sectioned.

9. The seismic cable of claim 1, wherein the signal cable includes a plurality of leads cabled by a third sheath.

10. The seismic cable of claim 1, wherein the signal cable includes at least one strengthening member.

11. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to the signal cable.

12. The seismic cable of claim 1, wherein the sensor modules transmit data and receive power over the signal cable.

13. The seismic cable of claim 1, further comprising:

a plurality of sensor modules electrically connected to and distributed along the signal cable; and

a plurality of electronics modules by which the signal cable is attached to the support cable at the points.

14. The seismic cable of claim 1, wherein the electronics modules are electrically connected to the signal cable at the points and mechanically connected to the support cable.

15. The seismic cable of claim 1, wherein the signal cable is attached to the support cable by a zipper mechanism.

16 The seismic cable of claim 1, wherein the plurality of points are spaced along the length of the signal cable in proportion to a length of the sensor module.

17. The seismic cable of claim 16, wherein the plurality of points are positioned between adjacent sensor modules

18. The seismic cable of claim 16, wherein the separations are created by pulling a rip cord fabricated in the seismic cable to detach the signal cable from the support cable.

19. The seismic cable of claim 1, further comprising a plurality of arms mechanically affixed to the support cable and rotationally connected to the signal cable to attach the signal cable to the support cable at the points.

20. The seismic cable of claim 19, wherein the arms are at least one of rigid and semi-rigid arms.

21. The seismic cable of claim 19, wherein the arms are mechanically fixed by a plurality of clamps.

22. The seismic cable of claim 19, wherein the arms are rotationally connected by a bearing.

23. The seismic cable of claim 19, further comprising a plurality of stops restraining movement of the rotational connection along the length of the signal cable.

24. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to and distributed along the signal cable and by which the support cable and the signal cable are joined.

25. The seismic cable of 24, wherein the support cable passes through a groove in the sensor modules.

26. The seismic cable of claim 1, wherein each of the sensor modules comprises a housing defining a groove therethrough through which the support cable runs.

27. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by a plurality of elastic devices.

28. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by freely moving through the groove relative to the sensor module.

29. A method for assembling a seismic cable, comprising attaching a support cable to a signal cable at a plurality of points spaced along the length thereof.

30. The method of claim 29, wherein attaching the support cable to the signal cable includes mechanically connecting an electronics module to the support cable and electrically connecting the electronics module to the signal cable.

31. The method of claim 29, wherein attaching the support cable to the signal cable includes zipping the signal cable to the support cable at the points.

32. The method of claim 29, wherein attaching the support cable to the signal cable includes separating the support cable and the signal cable between the points.

33. The method of claim 32, wherein separating the support cable and the signal cable includes pulling a rip-cord.

34. The method of claim 29, wherein attaching the support cable to the sensor includes mechanically affixing at least one of a rigid and a semi-rigid arm to the support cable and rotationally connecting the respective rigid or semi-rigid arm to the signal cable at each of the points.

35. The method of claim 29, wherein attaching the support cable to the signal cable includes connecting the support cable to the signal cable by a plurality of sensor modules.

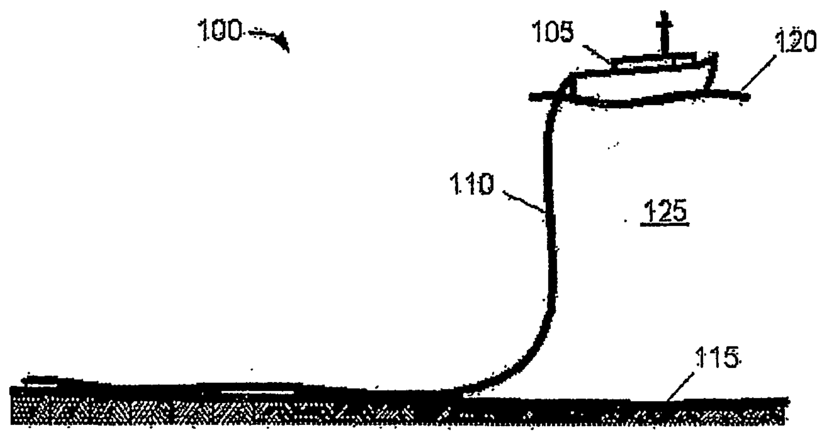

Figure 1

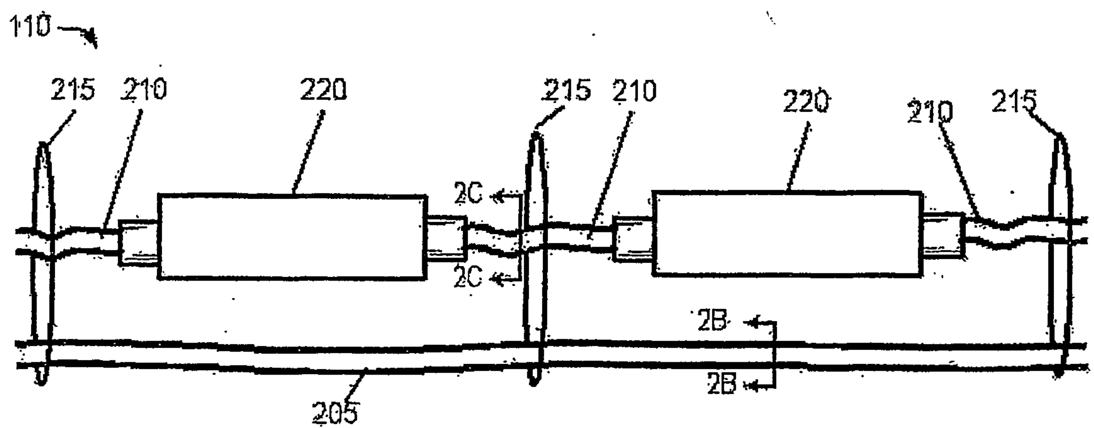

Figure 2A

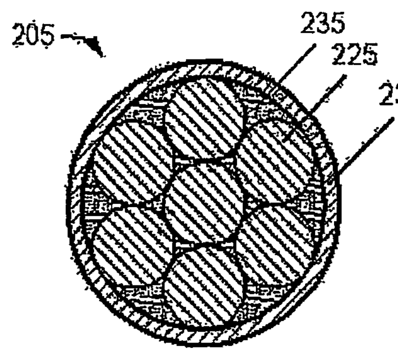

Figure 2B

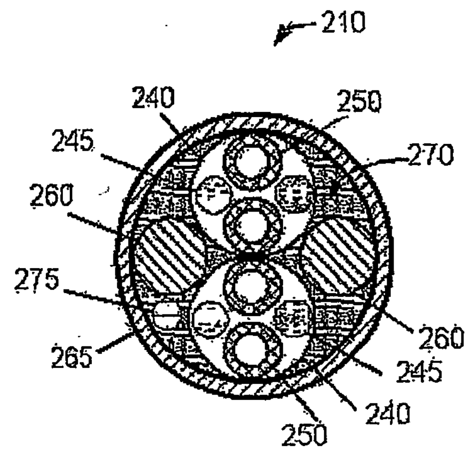

Figure 2C

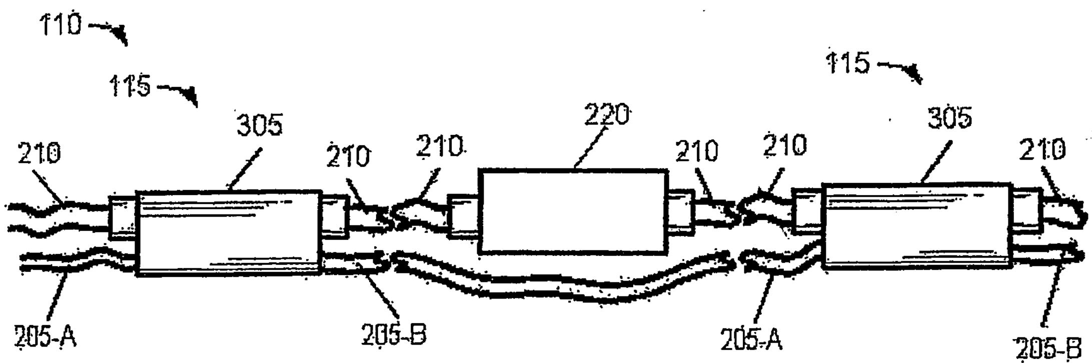

Figure 3

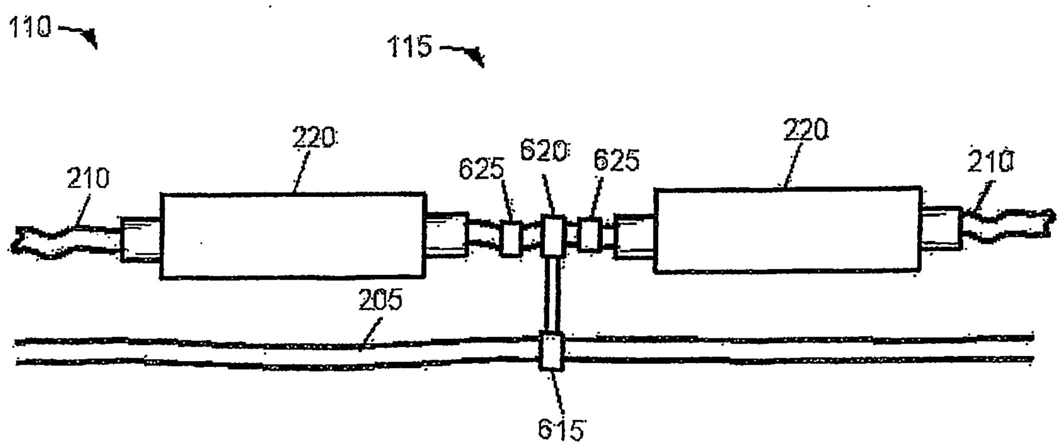

Figure 6

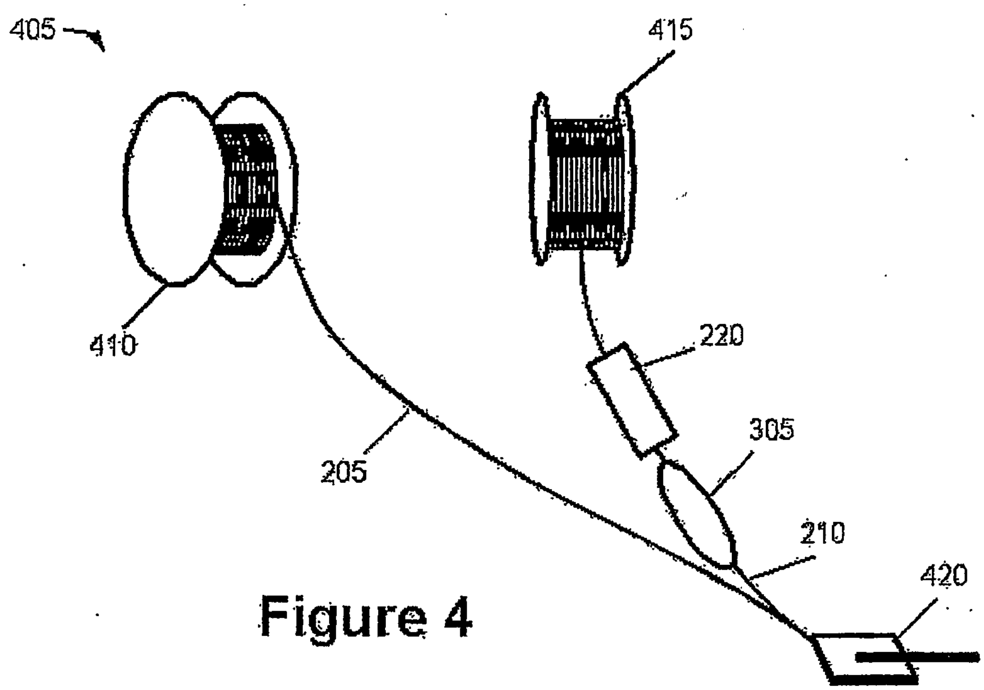

Figure 4

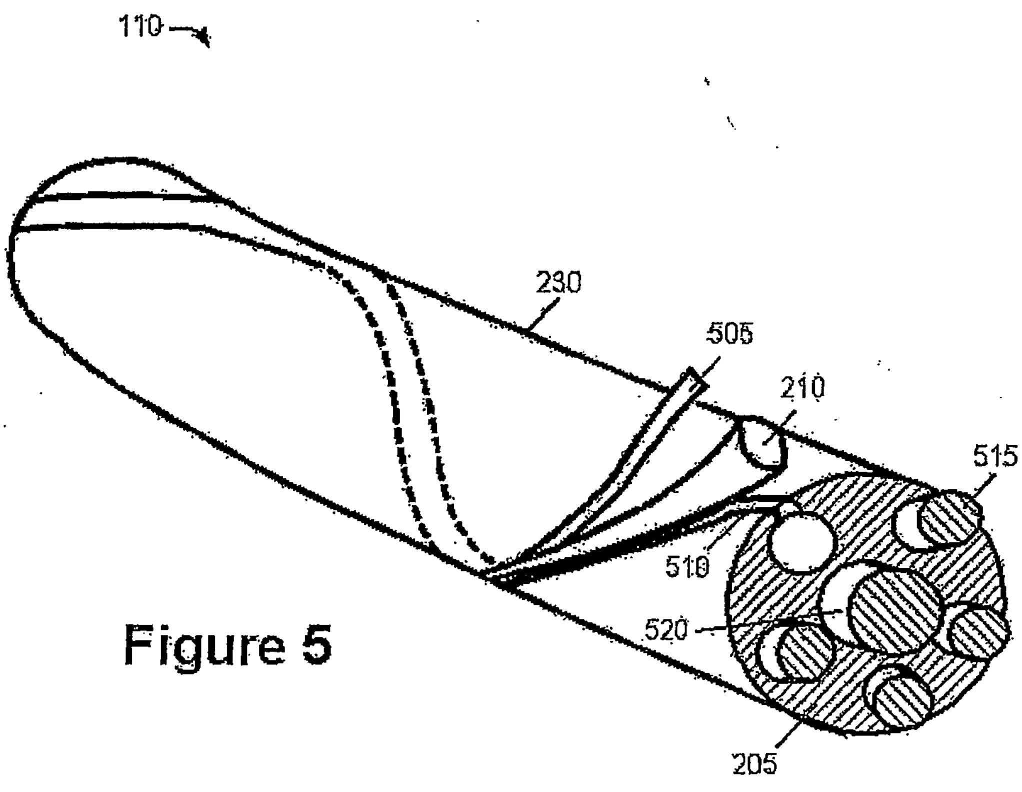

Figure 5

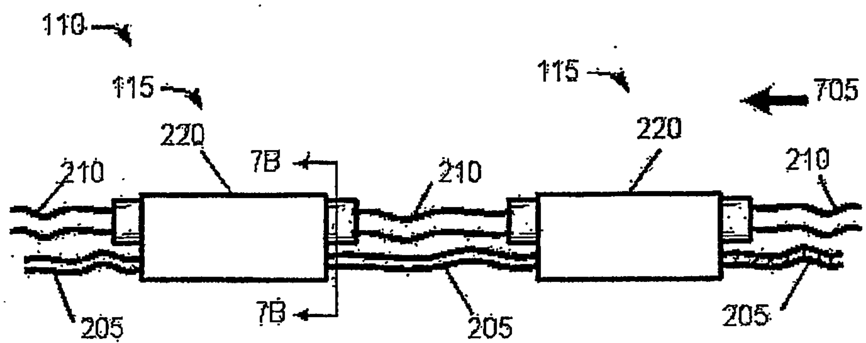

Figure 7A

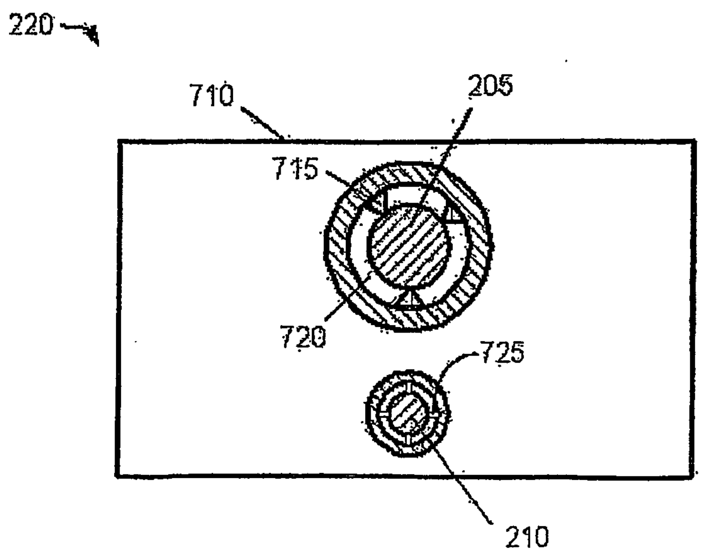

Figure 7B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/50702

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01V1/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 923 916 A (WOODWORTH JOHN H.) 2 February 1960 (1960-02-02) column 1, line 28 - line 31 column 1, line 67 -column 2, line 34 figures 2-5 ---	1,6-8, 11-14, 16,24, 27,29, 30,32,35
X	US 3 372 368 A (DALE JOHN R ET AL) 5 March 1968 (1968-03-05) column 3, line 2 - line 4 column 3, line 28 - line 38 column 3, line 59 - line 68 figure 1 ---	1,6,11, 12,29

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 February 2004	12/02/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Schneiderbauer, K

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/50702

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 398 276 A (KRUPPENBACH JOHN A) 9 August 1983 (1983-08-09) column 1, line 30 - line 56 column 2, line 50 - line 55 column 3, line 26 - line 40 column 3, line 60 - line 66 figure 2	1,6,11, 12,29
X	US 4 884 249 A (SNOOK CLIVE T) 28 November 1989 (1989-11-28) column 1, line 58 - line 60 column 3, line 16 - line 24 column 3, line 42 - line 56 figure 2	1,29
A	US 4 313 392 A (GUENTHER ROBERT O ET AL) 2 February 1982 (1982-02-02) column 1, line 39 - line 45 column 2, line 37 - line 68 column 3, line 56 - line 66 column 4, line 39 - line 66 figure 2	1-35

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 03/50702

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2923916 A	02-02-1960	NONE	
US 3372368 A	05-03-1968	NONE	
US 4398276 A	09-08-1983	CA 1164082 A1 DE 3174171 D1 EP 0048317 A2	20-03-1984 30-04-1986 31-03-1982
US 4884249 A	28-11-1989	NO 873149 A BR 8803710 A CA 1310103 C FR 2618911 A1 GB 2207405 A ,B NL 8801798 A	30-01-1989 14-02-1989 10-11-1992 03-02-1989 01-02-1989 16-02-1989
US 4313392 A	02-02-1982	NONE	

WO 2004/036252
PCT/EP2003/05070:

PATENT COOPERATION TREATY

Rec'd PCT/PTO 24 MAR 2005

From the INTERNATIONAL BUREAU

PCT

To:

SUCKLING, Andrew
Marks & Clerk
4220 Nash Court
Oxford Business Park South
Oxford OX4 2RU
ROYAUME-UNI

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

Date of mailing *(day/month/year)* 29 April 2004 (29.04.2004)	
Applicant's or agent's file reference AMS.P52316WO	**IMPORTANT NOTICE**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/EP2003/050702	07 October 2003 (07.10.2003)	12 October 2002 (12.10.2002)

Applicant

WESTERNGECO SEISMIC HOLDINGS LIMITED et al

1. Notice is hereby given that the International Bureau has **communicated**, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this notice:

   AU, AZ, BY, CH, CN, CO, DZ, EP, HU, JP, KG, KP, KR, MD, MK, MZ, RU, TM, US

   In accordance with Rule 47.1(c), third sentence, those Offices will accept the present notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:

   AE, AG, AL, AM, AP, AT, BA, BB, BG, BR, BZ, CA, CR, CU, CZ, DE, DK, DM, EA, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, ID, IL, IN, IS, KE, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MG, MN, MW, MX, NI, NO, NZ, OA, OM, PG, PH, PL, PT, RO, SC, SD, SE, SG, SK, SL, SY, TJ, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW

   The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-*bis*)).

3. Enclosed with this notice is a copy of the international application as published by the International Bureau on 29 April 2004 (29.04.2004) under No. WO 2004/036252

4. **TIME LIMITS for filing a demand for international preliminary examination and for entry into the national phase**

   The applicable time limit for entering the national phase will, **subject to what is said in the following paragraph, be 30 MONTHS** from the priority date, not only in respect of any elected Office if a demand for international preliminary examination is filed before the expiration of **19 months** from the priority date, but also in respect of any designated Office, in the absence of filing of such demand, where Article 22(1) as modified with effect from 1 April 2002 applies in respect of that designated Office. For further details, see *PCT Gazette* No. 44/2001 of 1 November 2001, pages 19926, 19932 and 19934, as well as the *PCT Newsletter*, October and November 2001 and February 2002 issues.

   In practice, **time limits other than the 30-month time limit** will continue to apply, for various periods of time, in respect of certain designated or elected Offices. For **regular updates on the applicable time limits** (20, 21, 30 or 31 months, or other time limit), Office by Office, refer to the *PCT Gazette*, the *PCT Newsletter* and the *PCT Applicant's Guide*, Volume II, National Chapters, all available from WIPO's Internet site, at http://www.wipo.int/pct/en/index.html.

   For filing a **demand for international preliminary examination**, see the *PCT Applicant's Guide*, Volume I/A, Chapter IX. Only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination (at present, all PCT Contracting States are bound by Chapter II).

   It is the applicant's **sole responsibility** to monitor all these time limits.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.+41 22 740 14 35	Authorized officer Ellen Moyse Facsimile No.+41 22 338 89 75

Rec'd PCT/PTO 24 MAR 2005

PATENT COOPERATION TREATY

REC'D 18 OCT 2004

WIPO PCT

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference AMS.P52316WO	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/EP 03/50702	International filing date *(day/month/year)* 07.10.2003	Priority date *(day/month/year)* 12.10.2002
International Patent Classification (IPC) or both national classification and IPC G01V1/38		
Applicant WESTERNGECO SEISMIC HOLDINGS LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 5 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand 15.04.2004	Date of completion of this report 15.10.2004
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Schneiderbauer, K Telephone No. +49 89 2399-7613

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1-17 as originally filed

Claims, Numbers

1-35 received on 24.09.2004 with letter of 24.09.2004

Drawings, Sheets

1/4-4/4 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1
	No:	Claims	29
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-35
Industrial applicability (IA)	Yes:	Claims	1-35
	No:	Claims	

2. Citations and explanations

see separate sheet

1.) **Reference** is made to the following documents:

D1: US-A-2 923 916 (WOODWORTH JOHN H.) 2 February 1960 (1960-02-02)
D2: US-A-3 372 368 (DALE JOHN R ET AL) 5 March 1968 (1968-03-05)
D3: US-A-4 398 276 (KRUPPENBACH JOHN A) 9 August 1983 (1983-08-09)
D4: US-A-4 884 249 (SNOOK CLIVE T) 28 November 1989 (1989-11-28)

2.) **Technical field**: seismic streamers

3.) Novelty (Art.33(1),(2) PCT) and inventive step (Art.33(1),(3) PCT):

3.1) The present application does not meet the requirements of **Article 33(1),(3) PCT**, because the subject-matter of claim 1 is not inventive over D4.

D4 discloses a seismic cable system comprising a tubular shaped elongated and flexible support structure (D4; ref.8 in fig.2; col.3, li.20,21) which supports an active electronic cable 9 (D4; col.3, li.18,19). Cable 9 is equipped with sensors. The active cable 9 (signal cable) is attached to the support cable at a plurality of points spaced along the length of the signal cable (D4; fig.2, col.3, li.42-55).
D4 does not clearly state if reference 13 in fig.2 indicates the means for reception of seismic signals (see also D4; col.2, li.6,7) which in fact would render D4 even novelty destroying over claim 1.
However, even if taking reference 13 not into consideration, it is clear to the skilled person that disposing the sensor moduls substantially at a predetermined location along the length of the seismic cable is state of the art in marine seismics when operating with streamers.
Therefore, the subject-matter of claim 1 cannot be considered as being inventive over the prior art as taught in D4.

3.2) The subject-matter of independent claim 29 is not new over the prior art as disclosed in D4.
D4 discloses a method for assembling a seismic cable, comprising: attaching a support cable (D4; ref.8) to a signal cable (D4; ref.9) at a plurality of points spaced along the length thereof (D4; fig.2).

3.3) The subject-matter of independent claim 29 is also not new with regard to the prior

art as disclosed in D1 and D2 (s. cited passages in the ISR), nor is it considered to be inventive over the prior art as disclosed in D3 (s. cited passages of the ISR). The subject-matter of claim 1 differs from D3 in that a support cable is used and not only a support wire which has the additional advantage of making the system more flexible and efficient. It is clear to the skilled person, also in the light of documents D1 or D2, that such a cable can easily be employed instead of a simple wire in order to arrive at such an advantage. Using a cable instead of a wire does therefore not constitute an inventive step.

3.4) The subject matters of dependent claims 6-8,11-14,16,24,27,30,32 and 35 are not inventive: they can be found in D1, D2 or D3 - **Art.33 (1),(3) PCT** (s. also the cited passages and figures in the ISR).

3.5) The subject-matters of dependent claims 2-5, 9,10, 15, 17-23, 25,26,28, 31, 33 and 34 are not considered to be inventive (**Art. 33(1),(3) PCT**). They appear to be a matter of normal design procedure in order to build a seismic cable system comprising a signal cable (with sensor devices) supported by a support cable.

4.) Industrial applicability (Art.33(1),(4) PCT):
Beyond any doubt the invention, as defined in claims 1-35 is industrially applicable.

CLAIMS

1. A seismic cable, comprising:

a support cable;

a signal cable attached to the support cable at a plurality of points spaced along the length of the signal cable; and

at least one sensor module disposed on the signal cable.

2. The seismic cable of claim 1, further comprising a first sheath enclosing the support cable and the signal cable.

3. The seismic cable of claim 2, wherein the first sheath comprises at least one of is a skin, a jacket or an extrusion matrix.

4. The seismic cable of claim 1, wherein the support cable includes a plurality of strengthening members.

5. The seismic cable of claim 4, wherein the strengthening members are cabled by a second sheath.

6. The seismic cable of claim 1, wherein the support cable includes at least one of a signal lead and a power lead.

7. The seismic cable of claim 6, further comprising an electronics module powered over the power lead and capable of transmitting data over the signal lead.

8. The seismic cable of claim 7, wherein the support cable is sectioned.

9. The seismic cable of claim 1, wherein the signal cable includes a plurality of leads cabled by a third sheath.

10. The seismic cable of claim 1, wherein the signal cable includes at least one strengthening member.

11. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to the signal cable.

12. The seismic cable of claim 1, wherein the sensor modules transmit data and receive power over the signal cable.

13. The seismic cable of claim 1, further comprising:

a plurality of sensor modules electrically connected to and distributed along the signal cable; and

a plurality of electronics modules by which the signal cable is attached to the support cable at the points.

14. The seismic cable of claim 1, wherein the electronics modules are electrically connected to the signal cable at the points and mechanically connected to the support cable.

15. The seismic cable of claim 1, wherein the signal cable is attached to the support cable by a zipper mechanism.

16 The seismic cable of claim 1, wherein the plurality of points are spaced along the length of the signal cable in proportion to a length of the sensor module.

17. The seismic cable of claim 16, wherein the plurality of points are positioned between adjacent sensor modules

18. The seismic cable of claim 16, wherein the separations are created by pulling a rip cord fabricated in the seismic cable to detach the signal cable from the support cable.

19. The seismic cable of claim 1, further comprising a plurality of arms mechanically affixed to the support cable and rotationally connected to the signal cable to attach the signal cable to the support cable at the points.

20. The seismic cable of claim 19, wherein the arms are at least one of rigid and semi-rigid arms.

21. The seismic cable of claim 19, wherein the arms are mechanically fixed by a plurality of clamps.

22. The seismic cable of claim 19, wherein the arms are rotationally connected by a bearing.

23. The seismic cable of claim 19, further comprising a plurality of stops restraining movement of the rotational connection along the length of the signal cable.

24. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to and distributed along the signal cable and by which the support cable and the signal cable are joined.

25. The seismic cable of 24, wherein the support cable passes through a groove in the sensor modules.

26. The seismic cable of claim 1, wherein each of the sensor modules comprises a housing defining a groove therethrough through which the support cable runs.

27. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by a plurality of elastic devices.

28. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by freely moving through the groove relative to the sensor module.

29. A method for assembling a seismic cable, comprising attaching a support cable to a signal cable at a plurality of points spaced along the length thereof.

30. The method of claim 29, wherein attaching the support cable to the signal cable includes mechanically connecting an electronics module to the support cable and electrically connecting the electronics module to the signal cable.

31. The method of claim 29, wherein attaching the support cable to the signal cable includes zipping the signal cable to the support cable at the points.

32. The method of claim 29, wherein attaching the support cable to the signal cable includes separating the support cable and the signal cable between the points.

33. The method of claim 32, wherein separating the support cable and the signal cable includes pulling a rip-cord.

34. The method of claim 29, wherein attaching the support cable to the sensor includes mechanically affixing at least one of a rigid and a semi-rigid arm to the support cable and rotationally connecting the respective rigid or semi-rigid arm to the signal cable at each of the points.

35. The method of claim 29, wherein attaching the support cable to the signal cable includes connecting the support cable to the signal cable by a plurality of sensor modules.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/50702

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01V1/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 923 916 A (WOODWORTH JOHN H.) 2 February 1960 (1960-02-02) column 1, line 28 - line 31 column 1, line 67 -column 2, line 34 figures 2-5 ---	1,6-8, 11-14, 16,24, 27,29, 30,32,35
X	US 3 372 368 A (DALE JOHN R ET AL) 5 March 1968 (1968-03-05) column 3, line 2 - line 4 column 3, line 28 - line 38 column 3, line 59 - line 68 figure 1 --- -/--	1,6,11, 12,29

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 February 2004	12/02/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Schneiderbauer, K

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 398 276 A (KRUPPENBACH JOHN A) 9 August 1983 (1983-08-09) column 1, line 30 - line 56 column 2, line 50 - line 55 column 3, line 26 - line 40 column 3, line 60 - line 66 figure 2 ---	1,6,11, 12,29
X	US 4 884 249 A (SNOOK CLIVE T) 28 November 1989 (1989-11-28) column 1, line 58 - line 60 column 3, line 16 - line 24 column 3, line 42 - line 56 figure 2 ---	1,29
A	US 4 313 392 A (GUENTHER ROBERT O ET AL) 2 February 1982 (1982-02-02) column 1, line 39 - line 45 column 2, line 37 - line 68 column 3, line 56 - line 66 column 4, line 39 - line 66 figure 2 -----	1-35

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT [illegible] 03/50702

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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			EP	0048317 A2	31-03-1982
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			NL	8801798 A	16-02-1989
US 4313392	A	02-02-1982	NONE		

MULTI-PART SEISMIC CABLE

1. FIELD OF THE INVENTION

This invention relates generally to seismic cable systems, and, more particularly, to a robust and reliable seismic cable system.

2. DESCRIPTION OF THE RELATED ART

Subsurface hydrocarbon accumulations are increasingly found in geologically complex areas. The ability to conduct accurate seismic surveys may help improve the discovery rates and even the production of such accumulations. Seismic surveying is a method of stimulating a geological subsurface formation with, *e.g.*, electrical, magnetic, and/or acoustic signals to acquire seismic data about the formation. From this data, one can predict tell whether the formation contains hydrocarbon deposits and, if so, where.

One type of seismic survey is generally referred to as a "marine" survey because it is typically conducted at sea, although this is not necessarily always the case. During marine seismic surveys, seabed seismic cable systems are deployed to the bed of a sea, lake, river, or marsh. The water depth may range from several thousand meters up to the water/land transition zone. Water currents of considerable speed may pass over the cable system and create instability and deterioration of the seismic data quality.

Seabed seismic cable systems generally are designed to meet two conflicting goals. First, the cable system must be robust and resistant to damage. For example, the cable

system must survive and operate at great water depth. Also, the cable system may be roughly handled during deployment and retrieval. Second, the cable system should be sensitive to acoustic vibrations and not compromise the quality of data recorded by the sensor units.

Although there are several types of seabed seismic cables, there are generalities in construction. A seabed seismic cable includes three main elements: stress members, leads, and a sheath. One or several stress members take the tension that can be applied to the seabed seismic cable during deployment and retrieval operations to protect other elements of the cable. The leads, which may be electrical or optical, transmit power and/or data, in analog or digital format, along the cable for collection and processing, *e.g.*, on a survey vessel. The sheath is a skin, jacket or extrusion matrix protecting the seabed seismic cable against, notably, water ingress.

One type of seabed cable is known as an "ocean bottom cable" ("OBC"), and is typically equipped with "takeouts." A full length of conventional OBC is seismic built, the jacket is then opened at the location were the sensors are located, and leads are extracted from the cable to form a take-out and connected to the sensors. The sensors are then attached to the cable.

These types of cable are prone to water intrusion, electrical leakage, and wire kinking, as the take-outs are submitted to a high level of strain during cable handling. These cables usually have an asymmetric cross-section at the sensors, and the response will change depending on how the sensors rest on the seafloor. These types of cables also expose the seismic receivers and the takeouts to a number potentially damaging obstacles on the seabed, thereby reducing the reliability of the collected data. Furthermore, because the takeouts are

extracted from the cable and not a separate component, the entire cable may need to be replaced if the takeouts are damaged, which can be expensive and time-consuming.

Improvements to this type of apparatus appear in U.S. Patent No. 6,294,727 to Orlean, which provides for an "overmolding" of the cable and the sensor units. Improvements also appear in U.S. Patent and 6,333,898 to Knudsen *et al.* and U.S. Patent No. 6,041,282 to Wardeberg *et al.* (collective referred as "steel armored cables"), which provide for a preparation of steel armored cable without takeouts. However, the Orlean and steel armored cables still suffer from the drawbacks mentioned above, including water intrusion, electrical leakage, and wire-kinking. Furthermore, the Orlean and steel armored cables usually suffer from the asymmetric cross-section at the sensor units.

Another type of seabed seismic cable system is commonly referred to as a logging type cable. Logging type cables typically have a full electrical/optical termination at each sensor unit, resulting in a high number of connection points. The high number of connection points negatively impacts the cable's reliability. Furthermore, the increased number of terminations makes the sensor unit large and heavy, which negatively impacts data quality.

Yet another type of seabed seismic cable system comprises conventional cables with sensor units integrated inside a protective cable jacket. One variation is known as a "streamer type" cable. The streamer type cable is an evolution of a towed seismic streamer for deployment on the seabed. The streamer type cable comprises spacers, sensor units, and a filler, which usually is oil. The streamer type cable has a constant diameter and therefore occupies a large volume when stored. An alternative variation is known as a "solid cable." One example of the solid cable is shown in U.S. Patent No. 6,333,897 to Knudsen *et al.*,

which can be produced with a constant diameter or a variable diameter. Both the constant diameter and the variable diameter cables pose potentially serious drawbacks. The cable with a constant diameter is extremely large, heavy and stiff. The cable with a variable diameter is difficult to manufacture.

The present invention is directed to overcoming, or at least reducing the effects of, one or more of the problems set forth above.

SUMMARY OF THE INVENTION

The invention comprises a seismic cable and a method for assembling such a seismic cable. The apparatus comprises seismic cable including a support cable and a signal cable attached to the support cable at a plurality of points spaced along the length of the signal cable. The seismic cable also includes at least one sensor module disposed on the signal cable. The method includes attaching a support cable to a signal cable at a plurality of points spaced along the length thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify like elements, and in which:

FIG. 1 illustrates a seismic survey vessel from which a seismic cable constructed and operated in accordance with the present invention is deployed;

FIG. 2A to **FIG. 2C** illustrate a first embodiment of the seismic cable of **FIG. 1** in accordance with the present invention wherein:

- **FIG. 2A** illustrates in a partially sectioned view of the seismic cable of **FIG. 1**, in accordance with one embodiment of the present invention;
- **FIG. 2B** illustrates the support cable of **FIG. 2A** cross-sectioned along line 2B-2B in **FIG. 2A**; and
- **FIG. 2C** illustrates the signal cable of **FIG. 2A** cross-sectioned along line 2C-2C in **FIG. 2A**;

FIG. 3 illustrates a partial view of the seismic cable of **FIG. 1**, in accordance with one particular embodiment of the present invention in which the support and signal cables are attached by the electronics modules;

FIG. 4 illustrates a storage and deployment mechanism for the seismic cable of **FIG. 1**, in accordance with a second embodiment alternative to that in **FIG. 3** in which the support and signal cables are joined by a zipper mechanism;

FIG. 5 illustrates a partial, perspective, cross-sectioned view of the seismic cable of **FIG. 1**, in accordance with a third embodiment alternative to those in **FIG. 3** and in **FIG. 4** in which the support and signal cables are fabricated together and then separated by a rip-cord;

FIG. 6 illustrates a partial plan view of the seismic cable of **FIG. 1**, in accordance with a fourth embodiment in which the support cable and the signal cable are attached by a rigid arm; and

FIG. 7A and **FIG. 7B** illustrate a fifth embodiment in a side, plan view and in an end, partially sectioned view (along line 7B-7B), respectively, which the support and signal cables are attached by the housings of the sensor modules.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

FIG. 1 illustrates a seismic survey system 100 in which a seismic survey vessel 105 has deployed a seismic cable 110 to the bed 115 from the surface 120 of a body of water 125. In the illustrated embodiment, the body of water 125 is part of an ocean. Consequently, the

bed 115 is a seabed (or, ocean floor). However, the invention is not so limited, as the invention may used for surveys conducted in fresh and brackish waters.

FIG. 2A illustrates a seismic cable 110 in accordance with one embodiment of the present invention. The seismic cable 110 comprises a support cable 205 and a signal cable 210 attached to the support cable 205 at a plurality of points 215 spaced along the length thereof. In the illustrated embodiment, the signal cable 210 further comprises a plurality of sensor modules 220, which will be discussed further below. In one embodiment, the spacing of the points 215 is approximately proportional to a length of the sensor modules 220 so that the points 215 are located between each of the sensor modules 220. However, the present invention is not so limited. In alternative embodiments, the points 215 may be located at any desirable location. For example, the points 215 may be located between every other sensor module 220 or between successive pluralities of sensor modules 220. For another example, a plurality of points 215 may be located between each pair of sensor modules 220.

As is shown in **FIG. 2B**, the support cable 205 includes one or more stress members 225 (only one indicated) providing tension to the seismic cable 110. The stress members 225 may be any type of stress member known to the art for handling tension in seismic cables. Examples of suitable stress members 225 include, but are not limited to, steel wire and utility cable. If more than one stress member 225 is employed, as in the illustrated embodiment, the stress members 225 may be cabled together in any suitable fashion known to the art. For instance, in the illustrated embodiment, the stress members 225 are jacketed together, *i.e.*, cabled together by enclosure in a jacket 230. Furthermore, in some embodiments, the support cable 205 may be filled with a filler 235 to, *e.g.*, help protect against water intrusion. The filler 235 may be of any suitable type known to the art.

As is shown in **FIG. 2C**, the signal cable 210 comprises, *inter alia*, a plurality of signal leads 240, and, in the illustrated embodiment, one or more power leads 260. The signal leads 240 may include electrical leads 245 such as a twisted wire pair of leads, a coaxial cable, and the like. The signal lead 240 may also include one or more optical fibers 250. As with the support cable 205, these elements may be cabled together in any suitable fashion known to the art. For instance, in the illustrated embodiment, the leads 240, 245, 250, 260 are jacketed together, *i.e.*, cabled together by enclosure in a jacket 265. Furthermore, in some embodiments, the signal cable 210 may be filled with a filler 270 to, *e.g.*, help protect against water intrusion. The filler 270 may be of any suitable type known to the art. In the illustrated embodiment, the signal cable 210 also includes a stress member 275 for providing extra support on forces exerted against the signal cable 210, although the invention is not so limited. In alternative embodiments, the signal cable 210 may not include the stress member 275 or may include a plurality of stress members 275.

Returning to **FIG. 2A**, the signal cable 210, in the illustrated embodiment, further comprises one or more sensor modules 220. The sensor module 220 includes one or more sensors (not shown). Examples of sensors include, but are not limited to, geophones, accelerometers, hydrophones, tilt meters, and magnetometers.

These sensors generate data in the course of survey operations and transmit that data over the signal cable 210 in a conventional manner. The sensors may include electronics for conditioning the signal and/or digitizing it. The sensor module 220 is typically connected to the signal cable 210 by one or more the sensor leads 240, 245, 250, 260 shown in Figure 2C. Note that the composition of sensors in each sensor module 220 may be the same or may be unique, depending on the implementation. To some degree, the choice of sensors may

influence the number and implementation of the signal and power leads (*e.g.*, the leads 240, 245, 250, 260 in **FIG. 2C**).

The data from the sensors may be transmitted to one or more electronics modules (not shown in **FIG. 2A**) located along the seismic cable 110 or between cable sections. The electronics module is connected to the signal cable the signal cable 210 by one or more of the signal leads (*e.g.*, the signal leads 240, 245, 250, 260 in **FIG. 2C**) of the signal cable. Alternatively, the functionality of the electronics module may reside in one or more of the sensor modules 220 in some alternative embodiments. The electronics module serves as a data transmission and power hub for the sensor modules 220. In one embodiment, the electronics module may comprise a high bandwidth bus capable of transmitting data between other electronics modules and to a computer or other computing device (not shown) on the seismic survey vessel 105 or at a remote location. In an alternative embodiment, the sensor module 220 may be connected to the signal cable 210 by a data bus (not shown). Regardless, one important function of the electronics module is to collect and forward the data generated and transmitted by the sensor modules.

In one embodiment, the sensor module 220 is sufficiently sealed to protect against water intrusion and physical damage. However, in alternative embodiments, the seismic cable 110 may be enclosed by a sheath, or protective outer covering (not shown).. In embodiments wherein the support cable 205 includes leads, the support cable 205 may also be enclosed by a sheath (not shown). The sheath protects sensitive electronics such as the signal cable 210 and sensor module 220 from water intrusion and physical damage. The protective outer covering can be any skin, jacket, or extrusion matrix known in conventional practice.

Although the support cable 205 bypasses the sensor module 220 as illustrated in **FIG. 2A**, in an alternative embodiment, a groove can be provided in the sensor module 220 such that the support cable 205 passes through the sensor module 220 via the groove. The support cable 205 can be acoustically decoupled from the sensor module 220 by one or more acoustic decoupling devices (not shown) between the groove and the support cable 205, such as springs or elastic devices, as will be discussed further below.

As was mentioned above, the signal cable 210 is attached to the support cable 205 at a plurality of points 215, shown generically in **FIG. 2A**. The invention admits wide variation in how this attachment may be accomplished, and may employ virtually any suitable attachment mechanism. **FIG. 3** – **FIG. 6** each illustrate various alternative embodiment employing and implementing different attachment mechanisms. More particularly:

- **FIG. 3** illustrates an embodiment in which the attachment is made through electronics modules 305 being connected to both a signal cable 210 and a support cable 205-A;
- **FIG. 4** illustrates the deployment of an embodiment in which the attachment is made through a zipper mechanism;
- **FIG. 5** illustrates an embodiment in which the support cable 205 and the signal cable 210 are separated after fabrication by a rip-cord 505; and
- **FIG. 6** illustrates an embodiment in which the attachment is made by a rigid arm 610.

Each of these alternative embodiments shall now be discussed more fully in turn.

FIG. 3 illustrates one embodiment of the seismic cable 110, in which an electronics module 305 separating two support cable sections referred in **FIG. 3** as a left support cable

section 205-A and a right support cable section 205-B section. As mentioned, the electronics module 305 is placed at intervals along the seismic cable 110 of **FIG. 1** and **FIG. 2A** and is generally placed between the support cable sections 205-A, 205-B.

As illustrated in **FIG. 3**, the signal cable 210 is directly connected to the electronics module 305. In one embodiment, the left support cable section 205-A terminates on one side of the electronics module 305 and begins anew at the right support cable 205-B at another side of the electronics module 305. In an alternative embodiment, the support cable sections 205-A, 205-B pass through the electronic module 305.

Although not illustrated in **FIG. 3**, it should be appreciated that at least of a portion the support cable sections 205-A, 205-B and signal cable 210 may be connected by some other attachment mechanism in addition to the attachment provided at the sensor module 305. For instance, the embodiment of **FIG. 3** might also employ the rigid or semi-rigid arm 610 in **FIG. 6**, discussed more fully below. Thus, some embodiments might use several different types of attachment mechanisms.

FIG. 4 illustrates an embodiment of the seismic cable 110 in **FIG. 1** alternative to that of **FIG. 3**. A storage and deployment mechanism 405 is shown, which stores a continuous length of support cable 205 in a support cable storage 410 and a continuous length of signal cable 210 in a signal cable storage 415. As mentioned, the sensor module 220 and the electronics module 305 are directly connected to the signal cable 210 and are stored along with the signal cable 210 in the signal cable storage 415. It should be appreciated that although the support cable storage 410 and the signal cable storage 415 are illustrated in a

common "spool" configuration, any method of storing a continuous length of cable known in conventional practice may be used.

The support cable 205 and the signal cable 210 are attached at one end by a zipper mechanism 420. As the support cable 205 is deployed from the support cable storage 410 and signal cable 210 is removed from signal cable storage 415, the zipper mechanism 420 is guided in the direction of the spools 410, 415, thereby automatically attaching the support cable 205 with the signal cable 210. The zipper mechanism 420 can be any mechanism known in the art for automatically clamping two members in a zipping fashion. For example, the zipper mechanism 420 may comprise a plurality of clamps that are individually operated to attach the support cable 205 with the signal cable 210. The plurality of clamps may be located on the support cable 205, the signal cable 210, or both. Another example of the zipper mechanism is a Velcro-based solution. Yet another example of a zipper mechanism is strong thread that attaches the signal cable to the support cable by sowing, wrapping or knitting.

Because the sensor module 220 and the electronics module 305 are attached to the signal cable 210 without tension, the signal cable 210 will be subjected to relatively gentler handling. Furthermore, this embodiment of the seismic cable 110 allows for greater operation depth and easier handling in adverse weather. The design also allows easier and faster replacement of component parts in the seismic cable 110. Still further, because the signal cable 210 and support cable 205 can be stored without tension, less space is needed in the signal cable storage 415 and the support cable storage 410, respectively. One important feature of this arrangement is that the signal cable 210 is handled and stored with virtually no tension. This creates an opportunity for the cable designer to avoid certain conflicting requirements like cable strength vs. unwanted inter-cable acoustic coupling.

Note that, in some embodiments, the electronics module can be carried as part of the support cable 205, as opposed to the signal cable 210. In such an embodiment, the support cable 205 comprises one or more electronics modules 305 (first shown in **FIG. 3**) connected to one or more leads in the support cable 205. The leads may be electrical or optical, depending on their purpose and the particular embodiment. The leads may be for transmitting data and power for the operation of the electronics modules 305. For instance, signal leads (*e.g.* the signal leads 240 shown in Figure 2C) may be used to transmit data from the electronics modules 305 to, *e.g.*, a computing device (not shown) located on the seismic survey vessel 105 (first shown in **FIG. 1**) or at the remote location. Similarly, leads may be employed for transmitting power from the survey vessel 105 to the electronics modules 305.

One example of such a seismic cable 110 is illustrated in **FIG. 5**. The support cable 205 and the signal cable 210 are manufactured together in one continuous unit and substantially enclosed by the protective outer covering 230. The signal cable 210 can be detached over short sections where the sensor modules (not shown in **FIG. 5**) are desired by pulling a rip-cord 505. Detaching the signal cable 210 from the seismic cable 110 leaves an empty groove 510. If the outer covering 230 is comprised of a thermoplastic, the rip-cord 505 can be heated by electrical current, for example, to ease pulling the rip-cord 510. Once the signal cable 210 is detached, it can be terminated and connected to the sensor module 220. The support cable 205, in the embodiment of **FIG. 6**, includes several signal leads 515 (only one indicated) over which control and data signals may be transmitted and a power lead 520 over which the electronic modules 320 may be powered.

FIG. 6 il lustrates an alternative embodiment of the attachment mechanism 215 of **FIG. 2A**. Aarm 610 separates the support cable 205 from the signal cable 210 at a sufficient distance such that the support cable 205 and the signal cable 210 do not contact during deployment. In alternative embodiments, the arm 610 may be rigid or semi-rigid. A semi-rigid arm 610 will flex along the direction of the signal cable 210 but be rigid in the direction of rotation about the signal cable 210. The arm 610 is attached to the support cable 205 by a clamp 615. The arm 610 should generally be attached loosely to the signal cable 210 such that excess torsion is not introduced into the signal cable 210. For example, as illustrated in **FIG. 6**, the arm 610 is attached to the signal cable 210 by a bearing 620 that allows the signal cable 210 to rotate freely around the signal cable 210 and move axially between two stop clamps 625.

FIG. 7A and **FIG. 7B** illustrate another alternative embodiment in which the support cable 205 and the signal cable 210 are attached by the housings of the sensor modules 220 themselves. The view in **FIG. 7B** is from the direction of the arrow 705 in **FIG. 7A** and sectioned along the line 7B-7B in **FIG. 7A**. As was alluded to earlier, the support cable 205 is acoustically decoupled from the housing 710 of the sensor module 220 by a plurality of elastic devices 715 (only one indicated), such as springs, as is shown in **FIG. 7B**. In some alternative embodiments, the elastic devices 715 may be omitted. Note that a plurality of electrical connections 725 (only one indicated) are conceptually illustrated between the signal cable 210 and the sensor module 220.

The elastic devices 715 are positioned between the support cable 705 and the sensor housing 710 in the groove 720 defined by the sensor housing 710 and through which the support cable 205 runs. Such decoupling techniques are known to the art, and one is more

fully disclosed in International Patent WO0214905, published February 21, 2002, in the name of James Martin, Nicolas Goujon, Frederik Naes, and Rune Voldsbekk.., and entitled "A HOUSING FOR A SEISMIC SENSING ELEMENT AND A SEISMIC SENSOR." However, other techniques may also be employed in alternative embodiments. For instance, some embodiments, the support cable is decoupled from the sensor housing 710 by being permitted to slide freely through the groove 720 relative to the sensor module 220.

The present invention facilitates acoustic decoupling of the sensor modules 220—and, hence, the sensors—from the stress member 205, which is rigid and under tension, and therefore improves the data quality recorded by the system 100. The various embodiments described herein provide a robust cable 110 capable of being subjected to rough handling when the cable 110 is deployed and/or retrieved. The robust cable 110 is further capable of being subjected to great water depth and pressure. Although the cable 110 is substantially robust, the cable 110 delivers higher data quality than previous cables. More particularly, in its various aspects and embodiments, the invention provides the following advantages over the state of the art:

- higher reliability of the connections to the sensor modules 220, as takeouts are eliminated;
- reduced number of connections;
- increased cable strength as terminations of the stress member 205 are eliminated;
- improved sensor-to-ground coupling due to the smaller and lighter sensor module 220;
- more precise data recording independent of how the sensor module 220 rests on the seafloor due to axial symmetry of the cable 110 and sensor module 220;

- mechanical decoupling between the sensor module 220 and the support cable, thus freeing the sensor module 220 from the stresses on the stress member 205 and improving data quality;
- high data quality independent of water depth;
- higher possibility for the same axial symmetry for the cable 110 as for the sensor module 220 and for positioning the sensor module 220 closer to the center of gravity of the sensor module 220—thereby providing consistent and repeatable independent of how the sensor module 220 lies on the seafloor;
- higher modularity of cable construction providing increased reparability, reconfiguration possibilities, improved depth-appropriate assembly, and even the possibility of omitting stress carrying support for shallow water operations;
- easier handling procedures, as the stress member 205 and the signal cable 210 can be separated for storage and shipping; and
- safer handling for components since the sensor module 220 can be stored separately from the stress member 205, thereby reducing danger to the sensor module 220 from tension on the stress member 205.

Note that not all of these advantages will be realized in every embodiment of the invention. Still other advantages may become apparent to those skilled in the art having the benefit of this disclosure.

This concludes the detailed description. The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the

particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

CLAIMS

1. A seismic cable, comprising:

a support cable; and

at least one sensor module disposed on a signal cable, the signal cable being attached to the support cable at a plurality of points spaced along the length of the signal cable whereby the or each sensor module is disposed substantially at a predetermined location along the length of the seismic cable.

2. The seismic cable of claim 1, further comprising a first sheath enclosing the support cable and the signal cable.

3. The seismic cable of claim 2, wherein the first sheath comprises at least one of is a skin, a jacket or an extrusion matrix.

4. The seismic cable of claim 1, wherein the support cable includes a plurality of strengthening members.

5. The seismic cable of claim 4, wherein the strengthening members are cabled by a second sheath.

6. The seismic cable of claim 1, wherein the support cable includes at least one of a signal lead and a power lead.

7. The seismic cable of claim 6, further comprising an electronics module powered over the power lead and capable of transmitting data over the signal lead.

8. The seismic cable of claim 7, wherein the support cable is sectioned.

9. The seismic cable of claim 1, wherein the signal cable includes a plurality of leads cabled by a third sheath.

10. The seismic cable of claim 1, wherein the signal cable includes at least one strengthening member.

11. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to the signal cable.

12. The seismic cable of claim 1, wherein the sensor modules transmit data and receive power over the signal cable.

13. The seismic cable of claim 1, further comprising:

a plurality of sensor modules electrically connected to and distributed along the signal cable; and

a plurality of electronics modules by which the signal cable is attached to the support cable at the points.

14. The seismic cable of claim 1, wherein the electronics modules are electrically connected to the signal cable at the points and mechanically connected to the support cable.

15. The seismic cable of claim 1, wherein the signal cable is attached to the support cable by a zipper mechanism.

16 The seismic cable of claim 1, wherein the plurality of points are spaced along the length of the signal cable in proportion to a length of the sensor module.

17. The seismic cable of claim 16, wherein the plurality of points are positioned between adjacent sensor modules

18. The seismic cable of claim 16, wherein the separations are created by pulling a rip cord fabricated in the seismic cable to detach the signal cable from the support cable.

19. The seismic cable of claim 1, further comprising a plurality of arms mechanically affixed to the support cable and rotationally connected to the signal cable to attach the signal cable to the support cable at the points.

20. The seismic cable of claim 19, wherein the arms are at least one of rigid and semi-rigid arms.

21. The seismic cable of claim 19, wherein the arms are mechanically fixed by a plurality of clamps.

22. The seismic cable of claim 19, wherein the arms are rotationally connected by a bearing.

23. The seismic cable of claim 19, further comprising a plurality of stops restraining movement of the rotational connection along the length of the signal cable.

24. The seismic cable of claim 1, further comprising a plurality of sensor modules electrically connected to and distributed along the signal cable and by which the support cable and the signal cable are joined.

25. The seismic cable of 24, wherein the support cable passes through a groove in the sensor modules.

26. The seismic cable of claim 1, wherein each of the sensor modules comprises a housing defining a groove therethrough through which the support cable runs.

27. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by a plurality of elastic devices.

28. The seismic cable of claim 26, wherein the support cable is acoustically decoupled from the housing by freely moving through the groove relative to the sensor module.

29. A method for assembling a seismic cable, comprising attaching a support cable to a signal cable at a plurality of points spaced along the length thereof.

30. The method of claim 29, wherein attaching the support cable to the signal cable includes mechanically connecting an electronics module to the support cable and electrically connecting the electronics module to the signal cable.

31. The method of claim 29, wherein attaching the support cable to the signal cable includes zipping the signal cable to the support cable at the points.

32. The method of claim 29, wherein attaching the support cable to the signal cable includes separating the support cable and the signal cable between the points.

33. The method of claim 32, wherein separating the support cable and the signal cable includes pulling a rip-cord.

34. The method of claim 29, wherein attaching the support cable to the sensor includes mechanically affixing at least one of a rigid and a semi-rigid arm to the support cable and rotationally connecting the respective rigid or semi-rigid arm to the signal cable at each of the points.

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35. The method of claim 29, wherein attaching the support cable to the signal cable includes connecting the support cable to the signal cable by a plurality of sensor modules.

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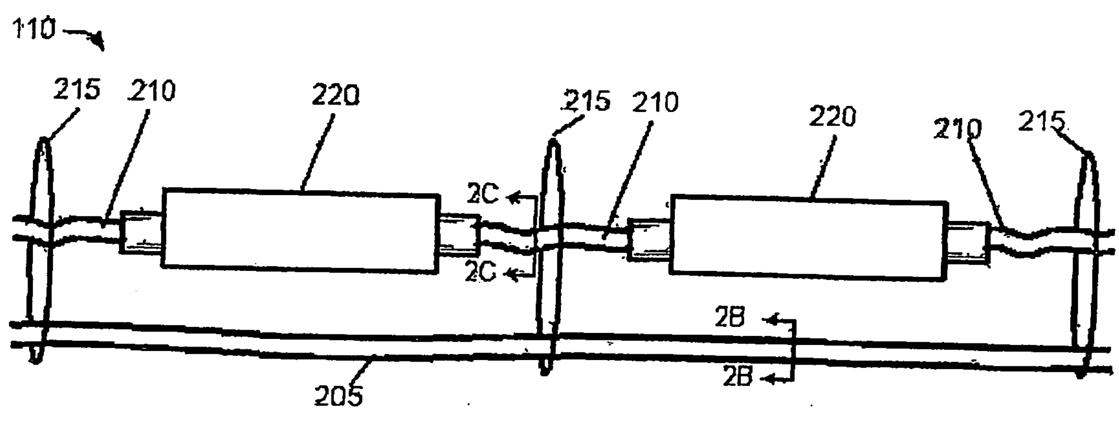

(57) Abstract: A seismic cable (110) and a method for assembling such a seismic cable are disclosed. The seismic cable (110) includes a support cable (205) and a signal cable (210) attached to the support cable (205) at a plurality of points spaced along the length of the signal cable (210). The seismic cable (110) also includes at least one sensor module (220) disposed on the signal cable (210). The method includes attaching a support cable (205) to a signal cable (210) at a plurality of points spaced along the length thereof.

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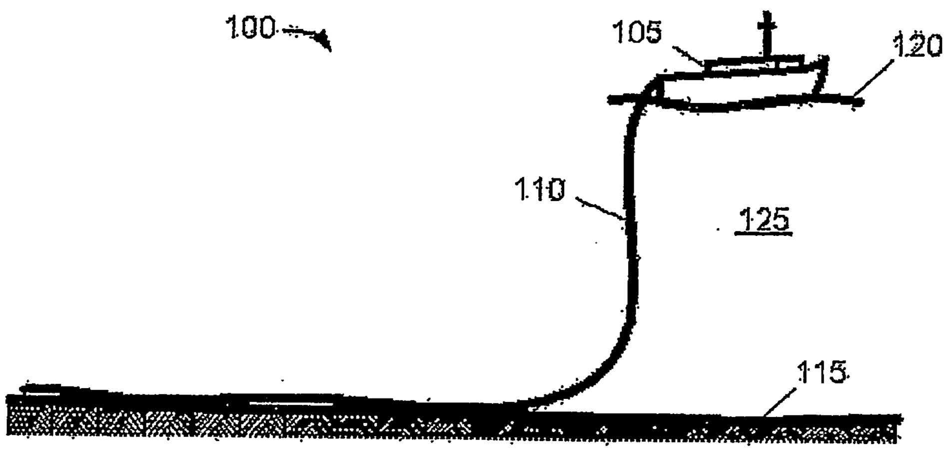

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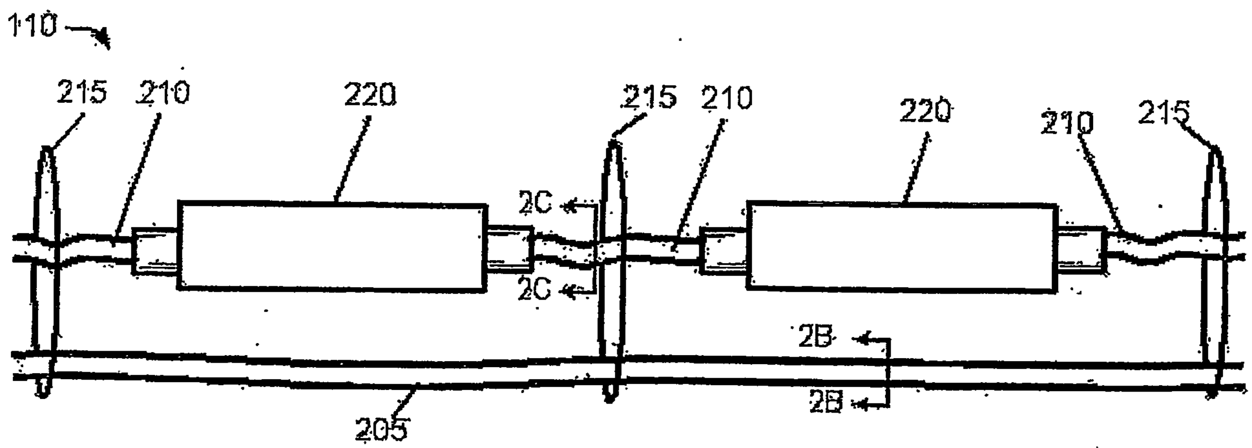

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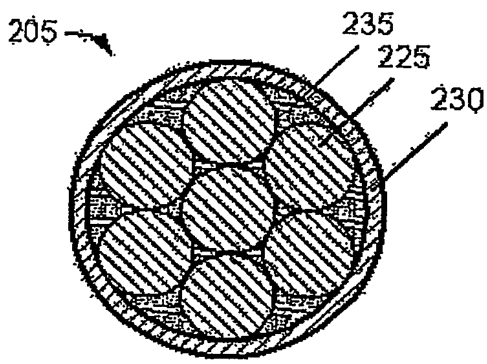

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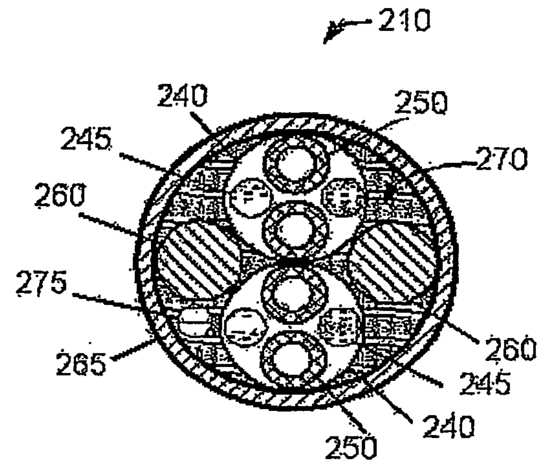

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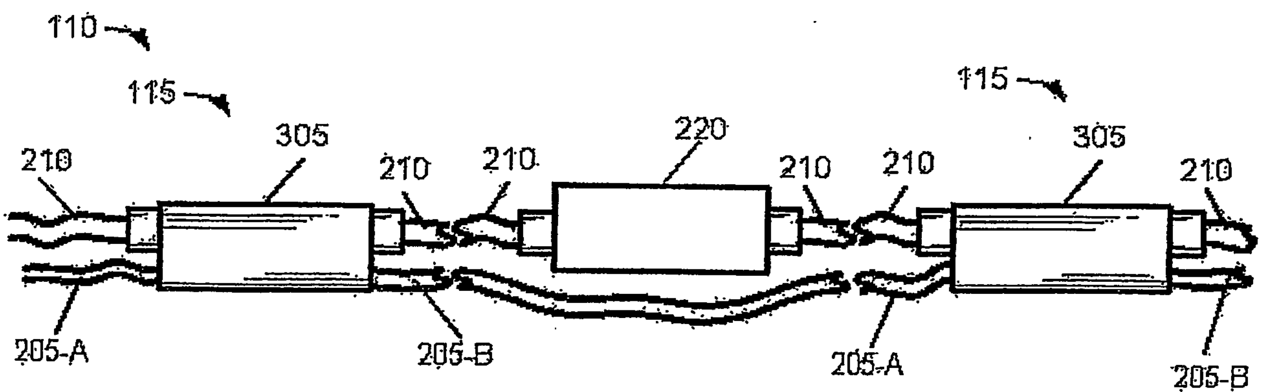
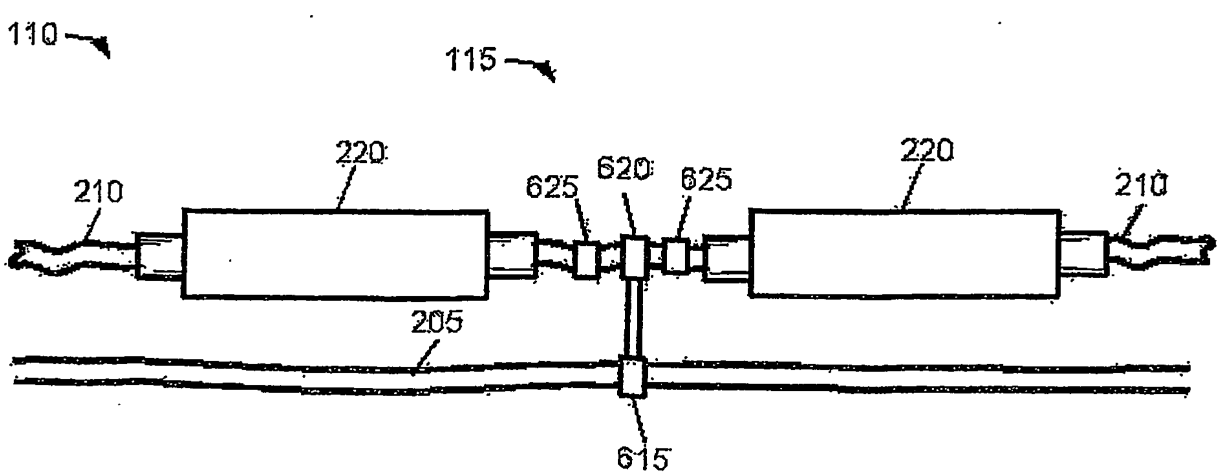


Figure 3



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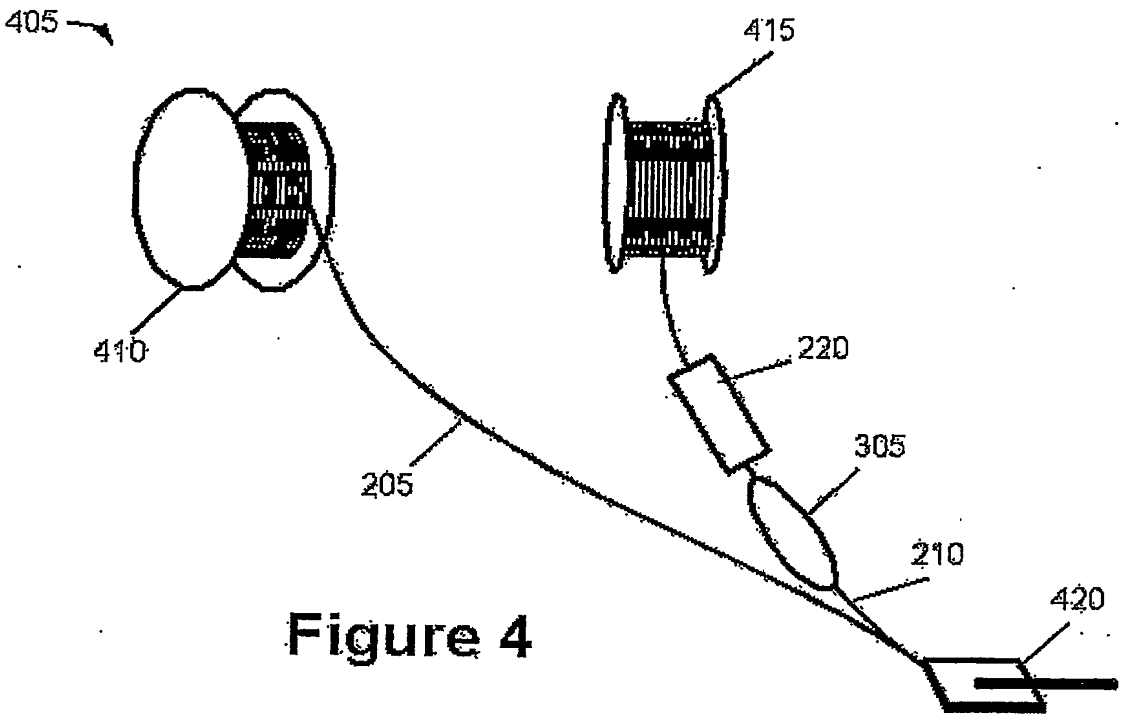

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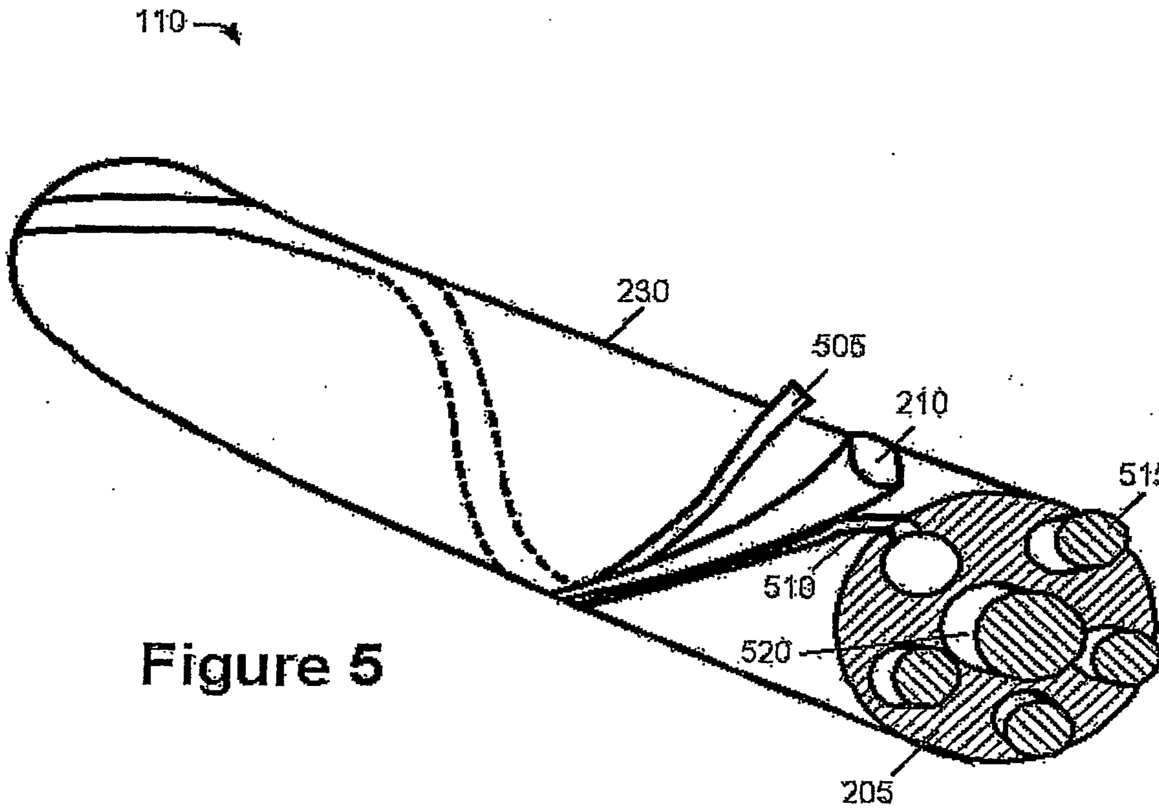

Figure 5

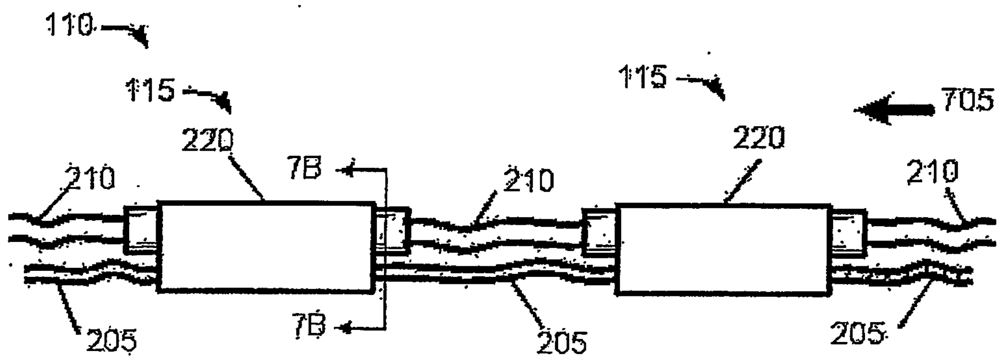

Figure 7A

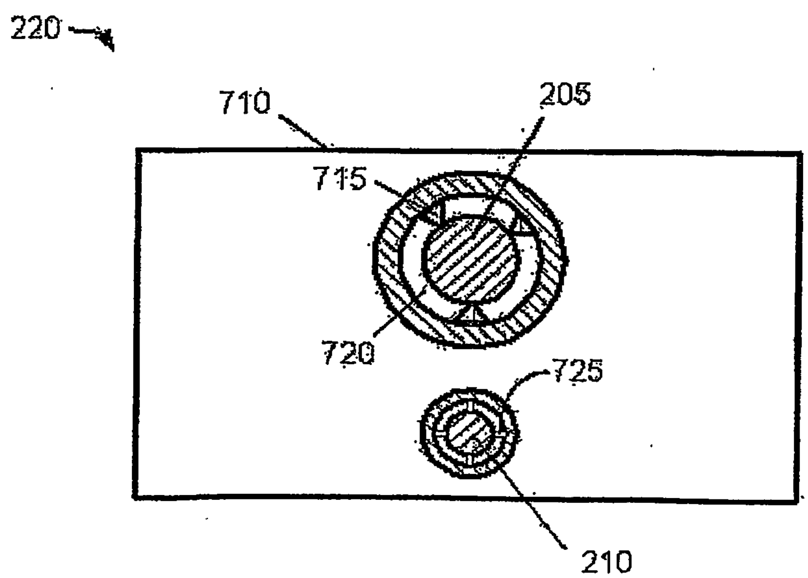

Figure 7B